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The influence of climate change communication on cognitive, emotional and behavioural engagement with adaptation among forest owners in Sweden

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Abstract

This thesis examines if, and how, climate change communication can promote individual engagement with adaptation. It tests if communication can affect intrapsychic conditions, behavioural intentions and individual action related to adaptation. To assess the effect of communication on individual engagement with adaptation, the thesis examines two different communication approaches: transmission-orientated and deliberation-orientated. To test the first approach, the thesis compares survey responses from 2014 of two different groups of forest owners from Sweden: Forest owners who participated in two climate change communication projects by the Swedish Forest Agency; and a group of randomly selected forest owners. To examine the second approach, the thesis evaluates results from a four-and-a-half-year long panel survey of 45 forest owners that participated in a communication project based on the concept of science-based stakeholder dialogues. The panel survey took place between 2013 and 2018. The thesis also uses qualitative data to complement the statistical analysis of the panel survey. Key findings include: First, intrapsychic conditions – personal appraisal of climate change risk, concern, trust in climate science, belief in personal knowledge, experience of extreme events and attribution of these experiences to climate change – can help explain individual engagement with adaptation. Second, both approaches to climate change communication have only a small effect on intrapsychic conditions, intentions and personal behaviour. Third, the potential of communication to promote engagement with climate change hinges on its perceived credibility, legitimacy and practical value. Fourth, the thesis highlights the limits of the psychological approach to research about individual adaptation and the need to understand climate change communication in its socio-economic context. The thesis offers boundary organisations insights into how to create credible, science-based and actionable knowledge. More long-term, mixed-method research is needed to better understand the influence of social norms and personal values on people's engagement with adaptation, and how communication can be combined with structural incentives to foster individual and collective action.

Summary

Even though there is consensus among scientists about the threat of climate change, many people who are at risk are not aware of it and are not taking action to protect themselves. Scientists and governments are increasingly using communication campaigns to help people understand and plan how they should adapt to the impacts of climate change. The idea behind many of these campaigns is that giving people scientific information is enough to make them change their opinions and behaviour. However, science and personal experience tells us that how people respond to expert advice is a lot more complex. Some might head warnings immediately, while others become more aware but don´t act differently. Some even dismiss advice entirely because they don´t find it credible. This is particularly true when it comes to climate change which is a very complicated and contentious matter.

With my thesis, I want to understand if, and how, science communication can help promote individual engagement with climate change adaptation. Engagement is about how people perceive risks from climate change and their ability to deal with them, how concerned they are, and what their intentions and actions are to protect themselves from climate change. To achieve its objective, my research focuses on the effects of science communication on non-industrial forest owners in Sweden. Forest owners in Sweden own more than half of the country´s forest and are at considerable risk from climate change which is expected to worsen the impact of storms, bark beetles, drought and wildfires.

My thesis looks at two different communication campaigns. The first was conducted by the Swedish Forest Agency and gave forest owners advice about climate risk and adaptation measures. The second campaign was based on interactive discussions between scientists and forest owners during meetings and workshops. I used surveys and interviews to measure if communication had made forest owners feel more engaged with adaptation. One of these surveys, which I conducted in 2014, compared 1493 forest owners that took part in the communication campaign by the Swedish Forest Agency with 909 randomly selected forest owners. Another survey assessed changes in 35 forest owners that took part in the second communication campaign. The survey study was conducted at three points in time: in 2013 before the start of the second campaign, immediately after and four-and-a-half years after in spring 2018.

My results show that forest owners that took part in communication campaigns felt that they had better knowledge how to adapt to climate change and that they could trust climate

science more. Talking to climate scientists and peers also helped them make sense of their personal experience with changing weather and climate conditions and connect them to climate change. However, my findings also suggest that over time, forest owners became less concerned about climate change and believed that its impacts on their property would be less severe. It also appears that communication didn´t change forest owners' intentions to adapt or how they managed their forest. Overall, many forest owners remained undecided if, and how, to adapt to climate change.

There are several potential reasons for why communication achieved relatively little in changing forest owners' opinions and actions about climate change. Many forest owners struggled to understand climate projections and what they meant for them. Some forest owners also remained distrusting of climate science. It could also be that forest owners became less concerned because they drew the conclusion that they weren´t as threatened by climate change as they thought they were. Another possible reason why communication had little effect on forest owners are social norms and economic pressures that they are under. The forest industry in Sweden is largely focused on cost-efficient production and short-term economic gain which makes it hard for private forest owners to make decisions that are not business-as-usual.

I conclude that more needs to be done to build lasting relationships between climate scientists and those needing to adapt to climate change. This could be achieved by organisations that are at the interface between science and practice. These organisations should focus on the joint development and communication of knowledge that people find relevant and credible. Furthermore, scientists also need to understand people´s experiences, values and needs to make sure that adaptation doesn´t end up in the quagmire of political polarization.

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Inspiration

Schwarze Röcke, seidne Strümpfe,
Weiße, höfliche Manschetten,
Sanfte Reden, Embrassieren –
Ach, wenn sie nur Herzen hätten!

Herzen in der Brust, und Liebe,
Warme Liebe in dem Herzen –
Ach, mich tötet ihr Gesinge
Von erlognen Liebesschmerzen.

Auf die Berge will ich steigen,
Wo die frommen Hütten stehen,
Wo die Brust sich frei erschließet,
Und die freien Lüfte wehen.

Auf die Berge will ich steigen,
Wo die dunklen Tannen ragen,
Bäche rauschen, Vögel singen,
Und die stolzen Wolken jagen.

Lebet wohl, ihr glatten Säle,
Glatte Herren! Glatten Frauen!
Auf die Berge will ich steigen,
Lachend auch euch niederschauen.

Heinrich Heine, Die Harzreise
(Translated by Charles Godfrey Leland)

Black dress coats and silken stockings,
Snowy ruffles frilled with art,
Gentle speeches and embraces –
Oh, if they but held a heart!

Held a heart within their bosom,
Warmed by love with truly glows,
Ah! I'm wearied with their chanting
Of imagined lovers' woes.

I will climb upon the mountains,
Where the quiet cabin stands,
Where the wind blows freely o'er us,
Where the heart at ease expands.

I will climb upon the mountains,
Where the somber fir-trees grow,
Brooks are rustling, birds are singing,
And the proud clouds chase.

Then farewell, ye polished ladies,
Polished men and polished halls!
I will climb upon the mountains,
Smiling down upon you all.

Student declaration

I declare that the thesis has been composed by myself and that the work has not be submitted for any other degree or professional qualification. I confirm that the work submitted is my own, except where work which has formed part of jointly authored publications has been included. My contribution and those of the other authors to this work have been explicitly indicated below. I confirm that appropriate credit has been given within this thesis where reference has been made to the work of others.

The work presented in Chapter 3 was previously published in Regional Environmental Change as *The relative importance of subjective and structural factors for individual adaptation to climate change by forest owners in Sweden* by myself (first author), Karin André, Åsa Gerger Swartling, Calum Brown (second supervisor), Mark Rounsevell (first supervisor) and Victor Blanco. This study was conceived by all the authors. I carried out 70 percent of the design and data collection, 100 percent the data analysis and 90 percent of the writing of the paper.

Research presented in Chapter 4 was previously published in Environmental Management as *Does climate change communication matter for individual engagement with adaptation? Insights from forest owners in Sweden* by myself (first author), Karin André, Åsa Gerger Swartling, Calum Brown (second supervisor) and Mark Rounsevell (first supervisor). This study was conceived by all the authors. I carried out 70 percent of the design and data collection, 100 percent the data analysis and 90 percent of the writing of the paper.

The work presented in Chapter 5 was previously published in Journal of Environmental Planning and Management as *Successes and shortcomings of climate communication: Insights from a longitudinal analysis of Swedish forest owners* by myself (first author), Karin André, Åsa Gerger Swartling, Calum Brown (second supervisor) and Mark Rounsevell (first supervisor). This study was conceived by all the authors. I carried out 50 percent of the design and data collection, 80 percent the data analysis and 90 percent of the writing of the paper.

The work presented in Chapter 6 has been submitted to Environmental Management as *The influence of climate change communication and personal forest values on engagement with adaptation among forest owners in Sweden* by myself (first author), Karin André, Åsa Gerger Swartling, Calum Brown (second supervisor) and Mark Rounsevell (first supervisor). I carried

out 65 percent of the design and data collection, 100 percent the data analysis and 90 percent of the writing of the paper.

Gregor Vulturius

Stockholm, June 2020

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Chapter 1: Introduction

1.1 Individual adaptation to climate change and climate change communication

Even in the increasingly unlikely event that the goal of the Paris Agreement to keep global average temperature rise to below 2 degrees Celsius above preindustrial levels can be met, societies and individuals will still need to adapt to the impacts of climate change caused by historical and future greenhouse gas emissions (IPCC 2018). Given that the world is currently on a path towards around 4 degrees Celsius of global warming by the end of the 21st century, there is an even greater urgency to promote public engagement with adaptation (IPCC 2014a). The Intergovernmental Panel on Climate Change (IPCC) defines climate change adaptation as a "process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects" (2014a, p. 6). This definition reflects the scientific literature, which refers to adaptation as both the process of adapting and the condition of being adapted, that is, adaptation measures and outcomes (Burton 1996; Füssel and Klein 2006; Moser and Ekstrom 2010).

Individuals are at risk of suffering the effects of climate change, but they can also play an important role in helping societies adapt to its impacts (Grothmann and Patt 2005). Individual adaptation to climate change is part of local and community-based adjustments to anticipate and cope with the impacts of climate change within the constraints of the socio-economic and cultural context (Smit and Wandel 2006). Individual adaption, however, cannot be simply understood as the result of objective adaptative capacity measured in structural determinants such as personal income or level of education (Brooks, et al 2005; Blennow et al. 2012).

Instead, research has highlighted how intrapsychic conditions such as personal values (Corner et al. 2014), beliefs (Reser et al. 2014), perceptions (van der Linden 2015), knowledge (Lee et al. 2015), emotions (Roeser 2012), experience of extreme events (Brügger et al. 2016) and confidence in personal abilities (Niles et al. 2016) are important in explaining how individuals will understand, plan and eventually manage adaptation action. Thus, individual adaptation to climate change can be described as a process that concurrently comprises

cognitive, emotional and behavioural engagement embedded within the broader socio-economic context (Lorenzoni et al. 2007; Wolf and Moser 2011).

To help individuals become more engaged with adaptation, researchers and decision makers are increasingly using communication interventions (Moser 2014). Climate change communication has been loosely defined as "any effort – explicit or otherwise – that aims to raise public awareness, understanding, and/or active engagement with the issue" (Markowitz and Guckian 2018, pp. 35–36). The IPCC acknowledges that climate change communication is a valuable approach to adaptation by raising awareness about climate change risk and by fostering learning about the costs and benefits of different adaptation options (IPCC 2014b). Climate change communication can be considered one of many social processes through which individuals construct (Pettenger 2007), amplify (Renn 2011) and learn (Reed et al. 2010) about climate change risks and adaptation.

While there is a growing body of literature on different communication techniques and strategies for how to engage individuals with adaptation (Ballantyne 2016), most of these studies involve only a small number of participants or are conducted at just one point in time (Moser 2014). More in-depth research is needed that makes use of larger samples (Arunrat et al. 2017) and that tracks changes in individual engagement over multiple years (Howell 2014). This type of research would help to build the scientific understanding of how climate change communication can effectively promote individual engagement with adaptation over the long term.

This thesis assesses the effects of climate change communication on individual engagement with adaptation among non-industrial, private forest owners (hereafter called forest owners) in Sweden. The research looks at the outcomes of two different approaches to communication: a transmission-orientated communication project carried out as part of the extension service programme of the Swedish Forest Agency (Nordström 2014) and a deliberation-orientated communication project based on the principles of science-based stakeholder dialogues (Welp et al. 2006a). To assess the influence of these two different communication interventions on forest owners, the thesis uses a mixed-methods approach that includes cross-sectional and panel surveys as well as interviews.

The following sections describe the background to and rationale for the case study (1.2), before outlining the research question, aims and approach (1.3), summarising the methodology, methods and materials (1.4) and outlining the structure of the thesis (1.5).

1.2 Background to and rationale for the case study

Almost 70 percent of Sweden is covered by forest. This includes some of Western Europe's last remaining wilderness (Allan et al. 2017). However, more than three-quarters of the forested area in Sweden is used for wood production and mostly consists of planted, even-aged, monoculture stands of Norway spruce and Scots pine trees (Swedish Forest Agency 2014). The forestry sector is an important source of income and employment in rural areas and around 3 percent of Swedish gross domestic product and ten percent of export value originates from forestry-related industries (Andersson and Keskitalo 2018). Importantly, more than 50 percent of productive forest in Sweden is owned by around 330,000 non-industrial private forest owners (Swedish Forest Agency 2014). These forest owners are increasingly faced with the impacts of climate change and the need for adaptation (Andersson et al. 2018).

According to the Swedish Commission on Climate Change (2007), climate change is expected to have profound impacts on Sweden. Depending on the climate scenario, temperatures are expected to increase by 1.5 - 2.5 degree Celsius (RCP 2.6), 2.5 - 4.0 degree Celsius (RCP4.5) or 4 - 6 degree Celsius (RCP8.5) by the end of the century (Kjellström et al. 2014). It is also anticipated that climate change will cause forest-specific impacts, such as an increased incidence of pests and invasive species (Jönsson and Bärring 2011), drought and forest fires (Lindner et al. 2014) and poorer ground conditions (Lindner et al. 2010). There is less certainty about the impact of climate change on the probability of storm damage and windfall (Blennow et al. 2010a). Climate change may also have some benefits for the forestry industry, chief among them increased growth due to higher temperatures and higher levels of atmospheric carbon dioxide (Swedish Commission on Climate and Vulnerability 2007). Recent research, however, suggests that the increased frequency of disturbances due to climate change may cancel out any increased growth potential (Reyer et al. 2017).

To adapt to the impacts of climate change, forest owners need to have the capacity to act. Forest owners in Sweden have been described as having high adaptive capacity due to their access to capital, knowledge, skills and technological innovation (Lindner et al. 2010). However, these broad indicators have limited capacity for explaining adaptive capacity and action by individuals (Adger et al. 2009). Pressure by the forestry industry to reduce costs, and global competition have been shown to reduce forest owners' adaptive capacity (Keskitalo 2008). Moreover, previous research has shown that cognitive and experiential

factors such as concern about the consequences of climate change (Eriksson 2014), and personal beliefs and experience of climate change are better at explaining engagement with adaptation among forest owners in Sweden (Blennow et al. 2012).

How individual forest owners adapt to the impacts of climate change will also depend on the legal and socio-economic conditions of the Swedish forest sector. Historically, the Swedish forest sector was legally obligated to maintain high levels of wood production for the paper pulp and timber industry (Lindahl et al. 2017). A revision of the Swedish Forestry Act in 1993 established a new environmental goal alongside the production of raw materials (ibid.) and gave forest owners greater autonomy in how they manage their forests (Appelstrand 2012). According to the Swedish Commission on Climate Change (2007), deregulation of forest policy means that forest owners' decisions now and over the next few decades will decide how the entire forest sector adapts to climate change. Deregulation also implies that, at least from a legal standpoint, forest owners are relatively free to choose between different forest management options for adapting their forest to climate change impacts (Schoene and Bernier 2012).

Given that forest owners have relative freedom over how they manage their forest (Lindahl et al. 2017), and following the recommendations of the Swedish Commission on Climate Change (2007), the Swedish Forest Agency has adopted an information-based strategy to promote adaptation (Keskitalo 2011). As part of this strategy, the agency has developed and communicated knowledge, tools and guidelines about climate change risk and adaptation options to stakeholders in the forest sector including non-industrial, private forest owners (Keskitalo et al. 2016). As part of its extension service programme, the Swedish Forest Agency engaged with more than 25,000 individual forest owners in climate change communication projects between 2009 and 2015 (Nordström 2014). Communication is also part of the new Action Plan on Adaptation by the agency, which was launched in 2017 (Eriksson et al. 2017).

Climate change communication targeting forest owners in Sweden is expected to promote individual engagement in the process of understanding, planning and eventually managing adaptation (Eriksson et al. 2017). As highlighted in the literature, there are structural (Brooks et al. 2005) and actor-specific (Adger et al. 2009) barriers that prevent individuals from adapting to climate change (Moser and Ekstrom 2010). Structural barriers are a product of the socio-economic context, such as legislative or social norms, whereas actor-specific barriers relate to individual perceptions, skills and access to social and economic capital

(Grothmann and Patt 2005; Wolf and Moser 2011). To understand the effects of climate change communication on individual engagement with adaptation, it is therefore necessary to identify these barriers and assess whether communication can help individuals to overcome them (Markowitz and Guckian 2018).

Previous research on forest owners in Sweden has shown that most of them are not concerned about climate change (Eriksson 2014) and struggle to understand how it will affect familiar and unfamiliar risks, as well as which forest management options are likely to be effective at adapting to changing climatic conditions (Keskitalo et al. 2016). Perceived uncertainty about climate change risks and lack of knowledge of and belief in the effectiveness of adaptation options represent further barriers to forest owners in Sweden planning for and eventually managing adaptation (Blennow and Persson 2009). Overcoming these cognitive and emotional barriers is made harder by the fact that taking measures to adapt to emerging and uncertain climate-related risks is a departure from the established forest management approach that focuses on maximising wood production and short-term economic gain (Keskitalo 2011) and that favours a business-as-usual approach to adaptation (Andersson et al. 2018).

Between 2013 and 2018 during which the empirical research for this thesis was undertaken, several notable events and shifts in the public debate about the Swedish forest sector occurred. In summer 2014, a large forest fire affected the county of Västmanland only a few hours by car from Stockholm. Research after the fire showed that individuals that were affected by the fire believed that climate change may lead to an increased risk of forest fires in the future (Lidskog et al. 2019). A series of forest fires occurred in 2018 which affected an area more than twice as big as the area affected in 2014. However, all empirical material used in this thesis had been collected before then.

The public debate about the Swedish forestry model also intensified since 2013 with opponents and proponents arguing about its climate change benefits and biodiversity impacts. At the time of the start of the thesis, the forest sector main argument was that forest-based biofuels have been key to lower Swedish road traffic emissions and could be scaled for export. However, the advent of the electric car and increasing criticism at the EU level about biofuels have made it more likely that biofuels from forestry will remain a Swedish niche product (Nykvist and Suljada 2017). Therefore, proponents of the status quo of the Swedish forest model have increasingly argued in favour of intensive forest management

because of its carbon sequestration potential. Indeed, Sweden's target of achieving net-carbon neutrality relies on negative emissions from the Swedish forest sector (Cintas et al. 2017). However, civil society and research is also becoming increasingly concerned about the adverse effects of maximizing carbon sequestration in the Swedish forest model – through e.g. logging residual tree stumps – on biodiversity (Felton et al. 2016).

In conclusion, the rationale for the case study is that private, non-industrial forest owners will play a key role in how the Swedish forest sector adapts to climate change as they enjoy relative independence in how they manage their forests. While forest owners in Sweden appear to have relatively high levels of capacity to adapt, most of them are currently not fully engaged in the process of understanding, planning for and managing adaptation. Communication of climate science has become a popular method of promoting individual engagement with adaptation, including in Sweden where it is part of the forest agency's adaptation policy. It is therefore of great scientific and societal value to understand whether – and, if so, how – climate change communication can help to overcome barriers to cognitive, emotional and behavioural engagement with adaptation.

In terms of professional development, the idea for this dissertation was born out of my master's thesis project for my degree in Spatial Planning and Development at Umeå University in which I assessed transformative learning for climate change adaptation among stakeholders in the Swedish forest sector. That project was made possible thanks to SEI which led me use qualitative interview data from the first phase of the Mistra-SWECIA program which will be described in the following section. A revised version of the master thesis was later published (Vulturius and Swartling 2015). Given my prior experience with topic, SEI decided to hire me in 2013 to conduct more research on individual adaptation among Swedish forest owners for the second phase of Mistra-SWECIA. The School of Geosciences of the University of Edinburgh was part of the second phase of Mistra-SWECIA program and I was offered, and gladly accepted, a position as a part-time PhD student in 2015 to turn my work for SEI into a PhD dissertation.

During my time in the Mistra-SWECIA program and as a PhD student, I presented my research at more than a dozen different scientific conferences as well as local meetings of forest owner associations in Sweden. I have also given several interviews to professional forestry journals, newspapers and radio stations and had the opportunity to run workshops on climate change communication for the Swedish Environmental Protection Agency and the Swedish Forest

Agency. On a more personal level, the thesis has given me the opportunity to combine my passion for nature with my passion for academic research.

1.3 Research question, aims and approach

The overarching question of this thesis is: Can climate change communication promote individual engagement with adaptation among forest owners in Sweden? The main objective is to improve the scientific understanding of how climate change communication affects intrapsychic conditions and intrapsychic responses related to individual adaptation. A further objective is to develop insights that can be useful in the design of future climate change communication projects in the Swedish forest sector and elsewhere.

To address the research questions and objectives in the context of the case study's background and rationale, the thesis has four specific aims:

1. Understand the effect of intrapsychic conditions and structural determinants of adaptive capacity on individual adaptation to climate change (Chapter 3);
2. Analyse the effect of climate change communication on individual engagement with adaptation (Chapter 4);
3. Assess the short- and long-term influence of climate change communication on personal engagement with adaptation, including behavioural change (Chapter 5);
4. Examine how climate change communication and domain-specific values influence personal engagement with adaptation over the short and long term (Chapter 6).

To achieve these aims, the thesis takes an actor-centred approach to research on climate change adaptation and assumes that many barriers to adaptation can only be overcome by the actors themselves (Eisenack et al. 2014). This approach, however, does not disregard the broader context in which individuals are embedded (Wolf and Moser 2011). Instead, it recognises the extensive body of research that has underlined the importance of personal values, risk perceptions and beliefs to public support for climate policies (Wiest et al. 2015; Lee et al. 2015; Singh et al. 2017; Poortinga et al. 2019) and individual adaption to climate change (Blennow et al. 2012; Niles et al. 2016; Arunrat et al. 2017).

In recognition of the fact that individual engagement with climate change adaptation is a complex psychological and socio-economic process (Bradley and Reser 2017), the thesis is not based on a single explanatory approach. Instead, it draws on the literature on intrapsychic and behavioural change, including the theory of planned behaviour (Ajzen

1991), the model of private proactive adaptation to climate change (Grothmann and Patt 2005) and the American Psychological Association's model of individual adaption to climate change (Swim et al. 2009). The thesis also considers findings from science and risk communication and their implications for adaptation communication (Ballantyne 2016). Chapter 2 discusses the relevant literature in detail.

1.4 Methodology, methods and materials

This thesis fills a methodological gap in current research on climate change communication for adaptation (Moser 2014) by making use of quantitative data from a cross-sectional survey of forest owners. Results from the cross-sectional survey are used to address the first two aims of the thesis – to assess and compare the effects of different intrapsychic and structural barriers and of climate change communication on individual engagement with adaptation. Cross-sectional surveys are regularly used in research on personal perceptions and beliefs about climate change (Reser et al. 2014; van der Linden 2015; McDonald et al. 2015), public support for mitigation (van der Linden et al. 2019) and adaptation policy (Singh et al. 2017). They are also frequently used to examine the effects of communication interventions on public health (Adebajo et al. 2015), people´s opinion about climate change (Stroud 2007) or meat consumption (Stea and Pickering 2019). However, only a few studies have used cross-sectional surveys to assess the effects of climate change communication on individual engagement with adaptation (Chowdhury et al. 2012; Arunrat et al. 2017).

Cross-sectional surveys offer advantages that make them an appropriate method for studying individual engagement with adaptation and the outcomes of climate change communication. First, the large sample size allows researchers to draw empirically based conclusions about the population of interest. Second, a survey-based research design provides an opportunity to collect data from samples of the same or different populations and compare their responses. Third, quantitative data from surveys can be analysed using statistical methods capable of quantifying the complex relationship between personal perceptions, emotions and behaviour, and how individuals respond to new information and experiences (Millsap and Maydeu-Olivares 2009). Therefore, quantitative data from cross-sectional surveys can help to build a more sophisticated understanding of the effects of climate change communication on cognitive, emotional and behavioural barriers to individual adaptation (Capstick et al. 2015).

However, data from a questionnaire collected at only one point in time are not well-suited to examining changes in individual engagement with adaptation over time (Ruspini 1999). Previous research has shown that personal intrapsychic and behavioural changes in response to newly learned information and experience related to climate change can fade overtime (Kreibich et al. 2011). To address the third and fourth aims of the thesis, which are concerned with the long-term influence of climate change communication on individual engagement with adaptation, the research also includes a panel survey of forest owners who participated in a communication project. Longitudinal studies have the advantage of measuring individual change over time, and of identifying and relating individual changes to events or interventions (García-Peña et al. 2015). While there have been a small number of longitudinal studies on the effects of climate change communication on individual engagement with mitigation (Abrahamse et al. 2007; Howell 2011, 2014), similar research on adaptation is currently lacking (Moser 2014).

Before describing the design of the cross-sectional survey and panel survey in greater detail, it is necessary to highlight the limitations of the methodology. To start with, it is difficult to ascribe reported cognitive, emotional or behavioural changes to a single event or intervention based on quantitative data (Jones and Harris 1967). There is a risk that changes in individual engagement with climate change might be attributed to climate change communication when they were in fact caused by other factors not included in the study design (Howell 2014). This can be described as a Type 1 error, whereby something other than the observed stimuli causes a “false positive" outcome (Field et al. 2012). While panel surveys are generally better suited to drawing inferences about the causal relationship between a stimuli and individual change (Ruspini 1999), they too suffer from attribution error (Howell 2014). Therefore, the results of both survey studies must be interpreted within their broader socio-economic context (see section 1.2) taking into consideration external influences such as extreme events (Demski et al. 2017) or any other developments that could have influenced forest owners’ views and behaviour in relation to climate change.

Table 1.1 lists the research activities undertaken for this thesis. The research process started in the autumn of 2013 at a workshop on climate change adaptation organised by the Mistra-SWECIA research programme. Mistra-SWECIA ran between 2008 and 2015 with the objective of promoting research on climate change impacts and adaptation in Sweden, with a focus on the forest sector (André et al. 2016). Conversations during the workshop with the Swedish

Forest Agency generated the idea of conducting a countrywide, cross-sectional survey of forest owners to assess the outcomes of two transmission-orientated climate change communication projects run as part of the agency's extension service programme between 2011 and 2014 (Nordström 2014). After receiving financial support from Mistra, the Swedish Foundation for Strategic Environmental Research, a draft version of the survey questionnaire was sent to Swedish Forest Agency officers and representatives of forest owner associations in October 2013 for comments. The survey was also tested in two pilot studies: first, a qualitative focus group meeting with forest owners in Southern Sweden; and second, a quantitative survey with 100 randomly selected forest owners.

The survey design was finalised in February 2014 and sent out to 6000 forest owners, made up of 3000 randomly sampled owners and 3000 owners who had previously taken part in one of the two climate change communication projects run by the Swedish Forest Agency. Chapters 3 and 4 provide more details about the survey and how it measured individual engagement with adaptation. Chapter 4 contains more information about the two Swedish Forest Agency climate change communication projects and how two different groups of forest owners where sampled. Both chapters also provide information on the statistical methods used to analyse the data.

Table 1.1: Research activities in order of their appearance in the thesis

Research activities	Chapter	Date	Appendix
Pilot study with forest owners	Chapters 3, 4, 5 and 6	October 2013	
Cross-sectional survey of forest owners	Chapters 3 and 4	March–June 2014	Appendix 1
Ex-ante questionnaire with participants in the focus group meetings (T-0)	Chapters 5 and 6	November 2013	Appendix 2
First focus group meeting	Chapters 5 and 6	November 2013	Appendix 3
Second focus group meeting	Chapters 5 and 6	February 2014	Appendix 4
Presentation about climate change	Chapters 5 and 6	February 2014	Appendix 5
Presentation about climate impacts and adaptation strategies for forest owners	Chapters 5 and 6	March 2014	Appendix 6
Third focus group meeting	Chapters 5 and 6	March 2014	Appendix 7
First ex-post questionnaire with participants in the focus group meetings (T-1)	Chapters 5 and 6	March 2014	Appendix 8
Follow-up interviews	Chapter 5	September 2014	Appendix 9
Workshop with participants from the focus group meetings	Chapters 5 and 6	November 2014	Appendix 10
Second ex-post questionnaire with participants in the focus group meetings (T-2)	Chapters 5 and 6	March–June 2018	Appendix 11

In response to calls for more deliberation-orientated climate change communication (Johnson 2012), researchers of the Mistra-SWECIA program, including the author of this thesis, designed their own communication project based on the theory of science-based stakeholder dialogues (Welp et al. 2006a). Drawing on earlier studies that used science-based stakeholder dialogues in participatory climate research (Welp et al. 2006b), the project consisted of three focus group meetings and one workshop over the course of one year (Table 1.1). In comparison with conventional focus group interviews, the focus group meetings were more structured, included scientific presentations about climate change impacts and forest management options and used participatory techniques such as brainstorming and ranking exercises to facilitate knowledge exchange between scientists and forest owners, as well as peer-to-peer learning among owners (Kasemir et al. 2003). Chapters 5 and 6 provide more detailed descriptions of the focus group meetings and the workshop.

To evaluate the effects of the deliberation-orientated communication project on personal short- and long-term engagement with adaptation, a panel survey consisting of three questionnaires was conducted. Participating forest owners were asked to fill in a questionnaire before the start of the project, after the end of the final focus group meeting and four-and-a-half years after the start of the project. The questionnaires contained many of the questions that were included in the cross-sectional survey covered in Chapters 3 and 4. As described in greater detail in Chapters 5 and 6, the questionnaire contained sets of identical questions about forest owners' general views on climate change and adaptation, perceptions of climate-related risks, and opinions about forest management options and personal forest management. The first questionnaire also included questions about forest-specific values, which are examined in Chapter 6.

Taken together, the thesis is largely based on quantitative data from cross-sectional and panel surveys. However, survey data suffers from the general limitations of quantitative research, first and foremost that it cannot say much about how individuals make sense of new information and experiences or the internal process of knowledge adoption and retainment (Mertens 2015). To address this shortcoming, Chapter 5 includes qualitative data from interviews with forest owners who participated in the climate change communication project. In this mixed methods design, the qualitative data supplements the quantitative data from the panel survey (Ruspini 1999), which helps to understand not just if, but also how climate change communication influenced individual engagement with climate change

(Gifford et al. 2011). The interviews took place between the final focus group meeting and the workshop. They were conducted by telephone and followed a semi-structured interview guide (Appendix 5). Further details about the interviews and how the qualitative data were analysed can be found in Chapter 5.

1.5 Outline of the thesis

Chapter 2 reviews the existing literature on individual adaptation and climate change communication. The chapter defines individual engagement with adaptation and discusses models of intrapsychic and behavioural change relevant to individual engagement with adaptation. It also reviews the theoretical background to and techniques and strategies for climate change communication for adaptation before presenting the implications of the literature for the thesis.

Chapter 3 addresses the first research aim of this thesis and examines the effect of intrapsychic conditions and structural determinants of adaptive capacity on individual engagement with climate change adaptation. It is based on an adapted version of the model of private proactive adaptation to climate change by Grothmann and Patt (2005). Results are drawn from the cross-section survey of randomly sampled forest owners in Sweden.

Chapter 4 focuses on the second research aim and analyses the effect of climate change communication on individual engagement with adaptation. It uses the same theoretical and methodological approach as Chapter 3 but compares the results from randomly selected forest owners with results from forest owners who participated in transmission-orientated climate change communication projects run by the Swedish Forest Agency.

Chapter 5 concentrates on the third research aim and assesses the short- and long-term influence of climate change communication on personal engagement with adaptation, including behavioural change. The chapter goes beyond the methodological scope of the two previous chapters and draws on the panel survey of forest owners who participated in Mistra-SWECIA's, deliberation-orientated communication project. It also examines cognitive, emotional and behavioural change.

Chapter 6 extends the scope of the thesis even further by examining the influence of forest-specific values and deliberation-orientated climate change communication on individual engagement with adaptation using the same panel of forest owners. It also investigates

whether communication changes the connection between forest-specific values and forest owners' views on and attitudes to climate-related risks and adaptation.

Chapter 7 summarises the results and key findings of the thesis and discusses its limitations. The final chapter also presents the overall conclusions of the thesis and makes recommendations for future research.

Chapter 2: Discussion of the literature on individual engagement with adaptation, models of intrapsychic and behavioural change, and climate change communication

This chapter first defines individual engagement with adaptation (2.1) before discussing models of intrapsychic and behavioural change relevant to climate change adaptation (2.2). The final two sections describe the theoretical background to and techniques and strategies for climate change communication for adaptation (2.3) before summarising the implications of the literature for the thesis (2.4).

2.1 Individual engagement with climate change adaptation

This section examines how individual engagement with adaptation can be defined in the context of the thesis case study. Broadly speaking, adaptation refers to both the process of adapting and the condition of being adapted in order to cope better with or adjust to new circumstances (Smit et al. 1999). Adaptation is a central concept in several major scientific disciplines such as biology, psychology, anthropology and geography, and is recognised as a necessary response to global environmental and climate change (Simonet 2010). The literature on societal adaptation has identified a wide range of human and socio-ecological systems at different scales that are adapting to climate change (Folke et al. 2005), including individual forest owners in northern latitudes (Keskitalo et al. 2011b). Previous research has shown that despite having high adaptive capacity (Lindner et al. 2010), psychological factors such as lack of concern are holding back forest owners in Sweden from taking adaptive actions (Eriksson 2014).

Thus, to better understand how communication can promote individual engagement with adaptation among forest owners in Sweden, is it necessary to consider the psychological dimension of climate change (Bradley and Reser 2017). Research has shown that climate change has a range of direct, indirect and psychosocial impacts that individuals need to adapt to (Doherty and Clayton 2011). In a task force report on climate change, the American Psychological Association (APA) defined adaptation as "a wide range of responses individuals can make to difficult circumstances including initial understandings, affective responses to situations, behavioural responses to situations, the process of selecting responses, and the

reciprocating impacts of responses on individuals, communities, and the physical environment" (Swim et al., 2009, pp. 52–53).

The APA's definition of individual adaptation is comparable to the concept of attitude. Attitude has been described as an intrapsychic condition that is expressed by the evaluation of an attitude object (Eagly and Chaiken 1993). In the context of the thesis, attitude objects can be experiences of extreme events or scientific information about climate change. Attitudes to objects result in three different types of responses. Cognitive responses refer to people's perceptions and beliefs (Fishbein and Ajzen 1975), affective responses involve feelings of concern and behavioural responses are people's actions and intentions to act (Eagly and Chaiken 1993). Importantly, cognitive, affective and behavioural responses to new information and experiences can also alter existing attitudes to attitude objects (Eagly and Chaiken 1998).

The APA also highlights in its report that individual engagement with adaptation is influenced by social processes. These processes represent the societal discourse about climate change and include media coverage, policy advocacy or science-driven communication about climate change. Importantly, social processes shape how individuals construct (Pettenger 2007), amplify (Renn 2011) and learn (Reed et al. 2010) about climate change risks and adaptation.

Furthermore, the APA also acknowledges that individual adaptation to climate change is shaped not only by intrapsychic and social processes, but also by socio-economic moderators. Research has shown that individuals' vulnerability to the impacts of climate change impacts and their ability to adapt to them depends on structural – institutional, economic or cultural – conditions, and that this shapes a person's objective adaptative capacity to deal with climate change risks (Brooks et al. 2005; Hinkel 2011).

In sum, individual engagement with adaptation has three key traits that are of interest in this thesis. First, individual engagement with adaptation can be understood as a complex psychological process that concurrently comprises cognitive, affective and behavioural aspects (Lorenzoni et al. 2007). Second, these aspects influence how individuals appraise, select and manage climate change risks and adaptation options (Moser and Ekstrom 2010b). Third, personal perceptions, motivation, capacity and action related to adaptation are shaped by structural moderators and social processes (Adger et al. 2009; Doherty and Webler 2016).

By considering these three traits, the thesis takes an actor-centred approach to adaptation research (Eisenack et al. 2014) that focuses on intrapsychic conditions (e.g. personal appraisal of climate change risks) and social processes (e.g. communication intervention about climate change) (Swim et al. 2009) to explain individual engagement with adaptation. Section 2.2 presents different models of intrapsychic and behavioural change related to climate change adaptation. It also discusses the psychological and social factors identified in these models that either impede or enable individual engagement with adaptation (Adger et al. 2009; Wolf and Moser 2011; Gifford et al. 2011).

2.2 Models of intrapsychic and behavioural change related to climate change risk and adaptation

Theory of planned behaviour

The theory of planned behaviour (TPB, Ajzen, 1991) is one of the most influential theoretical approach to intrapsychic and behavioural change in humans. It is an extension of the theory of rational action (TRA, Fishbein and Ajzen, 1975), which is built on the premise that people make rational decisions out of self-interest. In the TRA, people's behaviour is determined by their intention to perform that behaviour and this intention is, in turn, a function of their attitude to the behaviour and subjective norms (Ajzen and Fishbein 1980). According to the TRA, personal attitudes to behaviour are based on beliefs and evaluations of behavioural outcomes, whereas subjective values are based on normative beliefs and motivation to comply (see Figure 2.1). Importantly, the TRA assumes that intention is the immediate antecedent of behaviour. There is, however, extensive research on pro-environmental behaviour that has shown that intention is a necessary but not sufficient predictor of behavioural change (Bamberg and Möser 2007).

The TPB does not assume that behavioural intention automatically leads to action. Instead, it includes perceived behavioural control as a third antecedent of behavioural change (see Figure 2.1). Perceived behavioural control refers to personal beliefs about how difficult it is to change behaviour in the light of past experiences and anticipated obstacles (Ajzen 1991). The concept of perceived behavioural control is similar to the concept of self-efficacy developed by Bandura (1977a). Both concepts highlight the importance of perceived agency and capacity as necessary preconditions for voluntary individual behavioural change (Ruiter et al. 2001). People with high levels of perceived behavioural control/self-efficacy are more

likely to evaluate and adjust their behaviour in response to new experiences and changing conditions (Bandura 2001).

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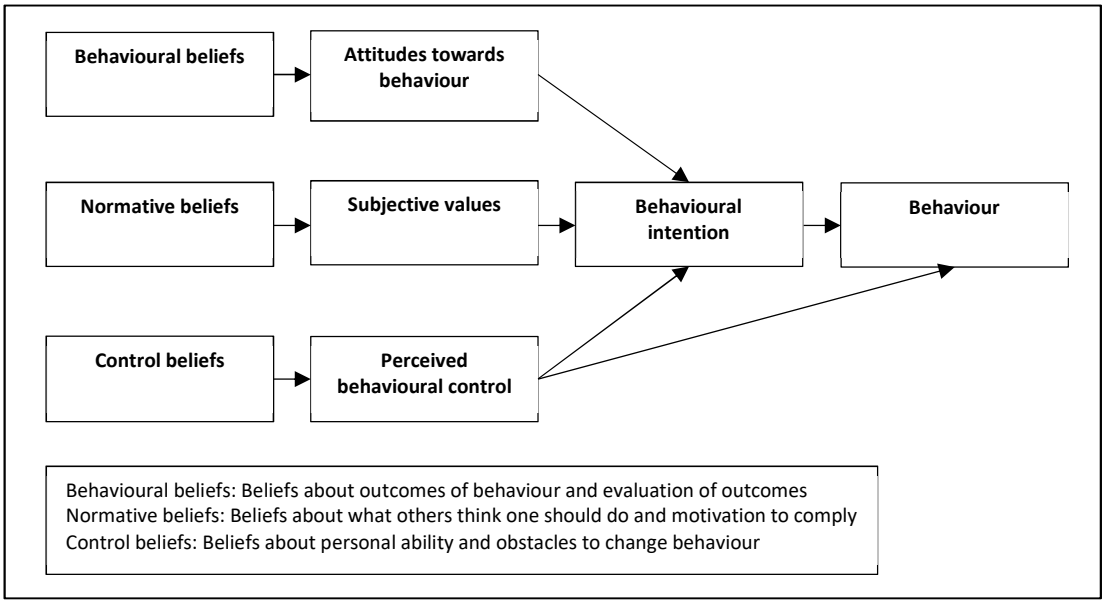

Figure 2.1: Theory of planned behaviour (Kollmuss and Agyeman 2002)

While the TPB has been used extensively in research on pro-environmental behaviour (Kaiser and Gutscher 2003), land use (Groeneveld et al. 2017), and climate change mitigation (Bamberg et al. 2003), only a small number of studies have used the concept in research about individual engagement with adaptation. In their work on farmers in Thailand, Arunat et al. (2017) found that individual intentions to adapt to climate change were most affected by perceived behavioural control, followed by attitudes to the outcomes of adaptation options and social norms. Also focused on farmers, but this time in New Zealand, Niles et al.

(2016) found that perceived capacity and self-efficacy, but not belief in social norms on acting on climate change, were important predictors of both intended and actual adoption. While not considering the influence of normative beliefs and control beliefs, Mase et al. (2017) still found that attitudes to innovative adaptation measures were an important factor behind adaptive behaviour by farmers in the United States.

Research on individual adaptation has also tried to expand the TBA to address findings about the importance of risk perception. In their research on Australian lobster farmers, Nursey-Bray et al. (2012) argue that risk perception is an independent driver of personal intentions to adapt to climate change, based on earlier research that found that risk perceptions matter in predicting personal intentions related to climate change irrespective of normative beliefs and subjective values (O'Connor et al. 1999). As described further below, however, more recent research has shown that social norms and personal values influence how individuals perceive the risks linked to climate change and choose to act on them (O'Brien and Wolf 2010; Kahan 2012).

Model of Proactive Adaptation to Climate Change

To address the importance of risk perception, Grothmann and Patt (2005) developed the Model of Proactive Adaptation to Climate Change (MPACC). This has become one of the most popular cognitive-behavioural models for explaining individual engagement with adaptation to climate change (Figure 2.2). It is based on Protection Motivation Theory (PMT, Rogers 1983), which has been used extensively in understanding adaptive and maladaptive responses to health threats (Milne et al. 2000).

According to the MPACC, individual engagement with adaptation is set in motion by social discourse on climate change (Grothmann and Patt 2005). This assumption can be connected to the social amplification of risk framework, which posits that psychological, social, institutional and cultural processes amplify or attenuate public responses to risks (Kasperson et al. 1988). Individuals (e.g. forest owners and climate scientists) process personal experiences with risks or mediated information about risks based on pre-existing perceptions and cognitive biases, turn these intrapsychic representations of risk into messages and communicate those messages to others (Renn 1991). By responding to risk-related messages through individual behaviour or social interaction, individuals and the organisations they represent actively engage in the social amplification of risks (Kasperson et al. 1988).

Unsurprisingly, climate change risks have been amplified because impacts are perceived to affect each functioning system of society from politics to economics and culture (Renn 2011). However, research has also shown that social amplification through risk-related messages alone cannot explain individual adaptation (Vasileiadou and Botzen 2014). While some of the differences in public opinion about climate change can be explained by the diversity of media and interpersonal sources (Whitmarsh 2009), many studies have shown that individuals draw different conclusions about the same information (Poortinga and Pidgeon 2005; Kahan et al. 2012; Schuldt et al. 2018).

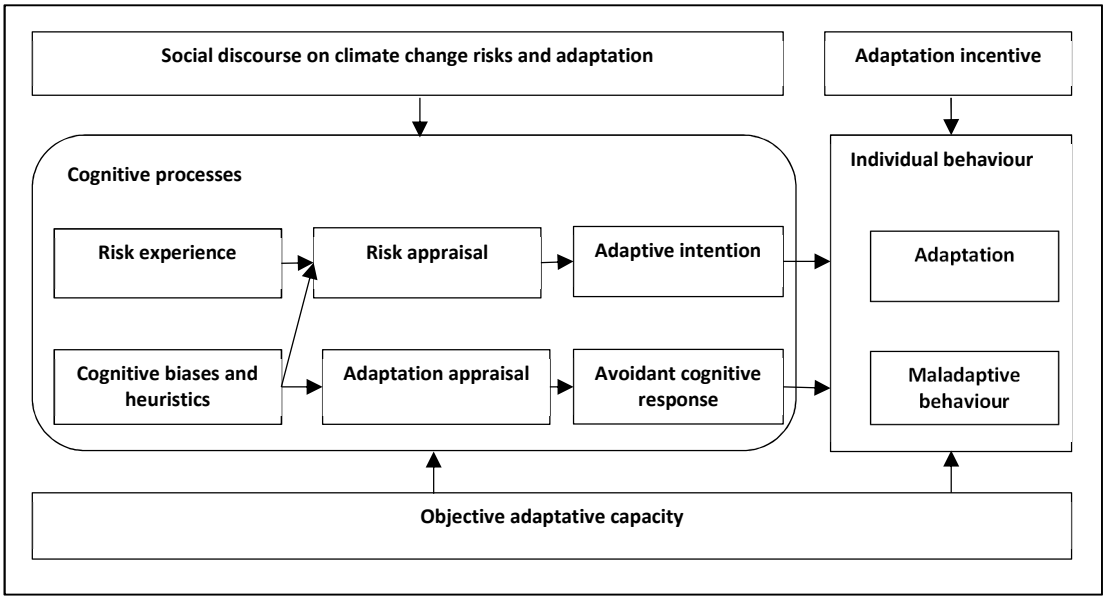

Figure 2.2: Simplified and adapted version of the Model of Proactive Adaptation to Climate Change (Grothmann and Patt 2005)

The MPACC highlights that how individuals respond to the social discourse and mediated information about climate change risk depends on two cognitive processes. In the first process, a person appraises the probability and severity of being negatively affected by climate change risks. Based on the assumptions made in the PMT (Maddux and Rogers 1983), the MPACC assumes that people will perceive risk to be more severe if it is an immediate threat to something that is of personal value. Furthermore, the MPACC also suggests that based on earlier research on natural hazard experience and individual preparedness (Weinstein 1989), personal experience with extreme events can heighten risk appraisal and intention to act.

However, there is mixed evidence for this hypothesis. While some studies have shown that personal experience of extreme events is an important predictor of personal perceptions of

climate change risk (van der Linden 2015) and intention to take climate action (Spence et al. 2011), others have shown that personal experience has no influence on personal concern (Dessai and Sims 2010) or willingness to change behaviour (Whitmarsh 2008). Recent research has even provided evidence of a "boiling frog" effect – extreme events are becoming socially normalised and people's reference point for normal conditions is based on the weather experienced in the recent past (Moore et al. 2019). As is described in greater detail below, whether experience with climate-related risk leads to individual engagement with climate change depends on whether individuals attribute their experiences to climate change (Blennow et al. 2012) as well as on the personal motivations and values that shape their opinion about climate change (Reser et al. 2014).

In the second cognitive process of the MPACC, a person appraises their own ability to take action to adapt to or cope with climate change risks. Importantly, appraisal of risks and adaptive capacity do not occur simultaneously. Instead, Grothmann and Patt (2005) highlight earlier research on self-efficacy and the adoption of healthy behaviour (Schwarzer 1992), which has shown that risk appraisal must exceed a threshold before people start contemplating the benefits of possible actions and evaluate their ability to actually perform them.

Like the TPB, the MPACC assumes that personal control beliefs and outcome beliefs play an important role in changing behaviour. In the MPACC, adaptation appraisal consists of perceived adaptation efficacy, that is, the belief that adaptive actions or responses will be effective in protecting oneself or others from being harmed by the risks; perceived self-efficacy, which refers to the person's perceived ability to perform or carry out these adaptive responses; and perceived adaptation costs, that is, the assumed costs vis-à-vis the benefits of making the adaptive response. Together, perceptions about the efficacy of adaptive actions, self-efficacy to perform these actions and the perceived cost-benefit of these actions are described by Grothmann and Patt (2005) as perceived adaptive capacity. The importance of perceived adaptive capacity is evident in Singh et al. (2017), which shows that lack of belief that adaptation measures will be effective reduces support for adaptation policies.

Furthermore, the MPACC also highlights that given the uncertainty about the future impacts of climate change (Heal and Kristrom 2002), cognitive biases and heuristics can have an irrational effect on risk perception and perceived adaptive capacity. Previous research has shown that cognitive biases and heuristics are expressions of the bounded rationality of

human decision making, which is characterised by a lack of reliable information regarding the possible consequences and alternatives, the limited cognitive ability of individuals regardless of their intelligence, and the limited amount of time available to make decisions (Kahneman 2003). Climate change has been called a textbook example of bounded rationality (Weber 2017).

Among the cognitive biases that affect personal appraisal of climate change risks and adaptation is optimism bias, which refers to the propensity for people to perceive their personal risk of being harmed by a certain threat (e.g., a forest fire) as smaller than the average risk (Hatfield and Soames Job 2001). People's tendency to discount spatially or temporally distant environmental risks is another cognitive barrier to individual perception of climate change risks (Gifford et al. 2011). Research has also found that people consider climate change to be a psychologically distant issue (Whitmarsh and Capstick 2018), that is to say that climate change is perceived as something that will only have impacts on remote locations or not in the near future (Brügger et al. 2015), or that it is uncertain (Morton et al. 2011) and not threatening to something that is of personal value (Corner et al. 2014) or relevance to one's own social identity (Frank et al. 2011).

Another bias is the availability heuristic, which describes a process by which people estimate risk by searching their memories for vivid experiences of a similar event (Tversky and Kahneman 1974). According to Grothmann and Patt (2005), availability heuristics could mean that individuals might overestimate the climate-related risks they have experienced and underestimate risks that they have no experience of. This suggests that individuals and societies will struggle to make decisions in anticipation of or response to the unfamiliar, catastrophic and irreversible impacts of climate change (Guillerminet and Tol 2008).

The MPACC differentiates different types of outcomes of personal risk and adaptation appraisal. Based on research in health psychology (Abraham et al. 1994), the model acknowledges that high awareness of risks can lead individuals to both adaptive and maladaptive responses. Maladaptive responses include avoidant cognitive responses or behavioural responses that increase personal exposure and vulnerability to climate change risks. The literature has identified several avoidant cognitive responses, such as, denial, wishful thinking, fatalism and apathy.

Denial that climate change is occurring, that it has any anthropogenic cause or that one's own actions play a role in climate change is frequently linked to mistrust of climate science,

perceived uncertainty about climate change and opposition to advice and policy (Gifford 2011). Denial can also lead to apathy (O'Neill and Nicholson-Cole 2009) and fatalism (Simonet and Fatorić 2016) acting as an affective barrier to adaptive action. Wishful thinking, on the other hand, describes the tendency of individuals to hope that the risk will not turn out to be as bad as anticipated (Morton et al. 2011), that someone else will take responsibility for adaptation and climate change impacts (Lees 2016) or that technological fixes can resolve climate change before adverse impacts occur (Lorenzoni et al. 2007). Furthermore, even when individuals accept the reality and uncertainty of climate change, believe in expert advice and not in simple fixes, there is ample evidence to suggest that they will still struggle to correctly understand, plan and manage adaptation (Ziervogel et al. 2014), which can lead to maladaptation (Juhola et al. 2016).

Despite all the different cognitive barriers and risks of maladaptive responses, the MPACC assumes that individuals can still make decisions that help them adapt to the impacts of climate change. Following the definition of the IPCC (2014a), adaptive responses are defined by the MPACC as responses that avoid impacts from climate change and increase the potential benefits of climate change. Like the TPB, however, the MPACC does not assume that individual intentions to take adaptive action will automatically lead to behavioural change. Instead, Grothmann and Patt (2005) stress that individuals also need to have the objective capacity, that is, access to financial resources, knowledge and social capital (Tinch et al. 2015), to achieve their adaptation aims, and to incentives such as economic subsidies for adaptation measures (Valinger et al. 2014).

Model of individual adaptation to climate change by the American Psychological Association

In their task force report on climate change (Swim et al. 2009), the APA also developed its own model of individual adaptation. In the report, the APA uses the term coping rather than adapting to connect to research on individual disaster preparedness, response and recovery (Reyes and Jacobs 2006), environmental stress and individual coping models (Baum and Fleming 1993). In this field of research, coping encompasses both reactive as well as proactive actions to reduce exposure and vulnerability to disaster risks (Lazarus and Folkman 1999). Similarly, the literature on resilience (Folke et al. 2010) and climate change adaptation (Smit and Wandel 2006a) uses the term coping to describe an individual's or a community's capacity to adapt to climate change impacts within physical and socially defined limits (Adger

et al. 2009; Dow et al. 2013). The term adaptation, however, is used below instead of coping when discussing the APA model.

The APA model draws on several psychological models concerned with personal responses to risks, including the stress, appraisal and coping model (Lazarus and Folkman 1999), PMT (Maddux and Rogers 1983) and the health belief model (Becker 1974). Although none of these models were developed with climate change in mind, they share a lot of traits with the literature on individual adaptation to climate change by focusing on the role of risk perception, perceived behavioural control and beliefs about behavioural outcomes.

Figure 2.3 shows an adapted version of the APA's model of individual adaptation to climate change. Like the MPACC, the model recognises mediated experience with climate change impacts, such as media reports or communication interventions by climate scientists, as a driver of individual engagement with adaptation. Furthermore, the APA model also acknowledges that the impacts of climate change can be independent triggers of individual adaptation. The literature has shown that responses to climate change impacts may differ depending on whether the impacts are direct or indirect (Daniels et al. 2011), local or global (Benzie and Persson 2019), linear or non-linear (Rial et al. 2004), abrupt or slow-onset (Held et al. 2010) and reversible or irreversible (Solomon et al. 2009). Like the MPACC, individuals respond to experienced or mediated impacts of climate change by appraising likely levels of probability, severity and their own personal resilience, and by appraising the efficacy of adaptation options, their self-efficacy in implementing and managing these options, the costs and benefits of options and socio-economic constraints (Swim et al. 2009).

Unlike the MPACC, however, the APA model also emphasises that how individuals respond to experienced and mediated impacts of climate change is influenced by the causal attributions they make for climate change. While earlier research has shown that individuals struggle to connect personal experience with climate change (Whitmarsh 2008), more recent studies have shown that people are capable of correctly attributing personal experience of extreme events and changing climatic conditions to climate change (Ogalleh et al. 2012; Akerlof et al. 2013; Arunrat et al. 2017). Lay people's ability to recognise the impacts of climate change is matched by improvements in the science of attributing extreme events to climate change (Fischer and Knutti 2015; Huggel et al. 2015). In terms of individual engagement with adaptation, research has shown that for personal experience to result in increased awareness (Reser et al. 2014), intention (Morris et al. 2016) and behavioural

change (Blennow et al. 2012), it matters that people believe that their experiences of extreme events or changing weather conditions are a consequence of climate change.

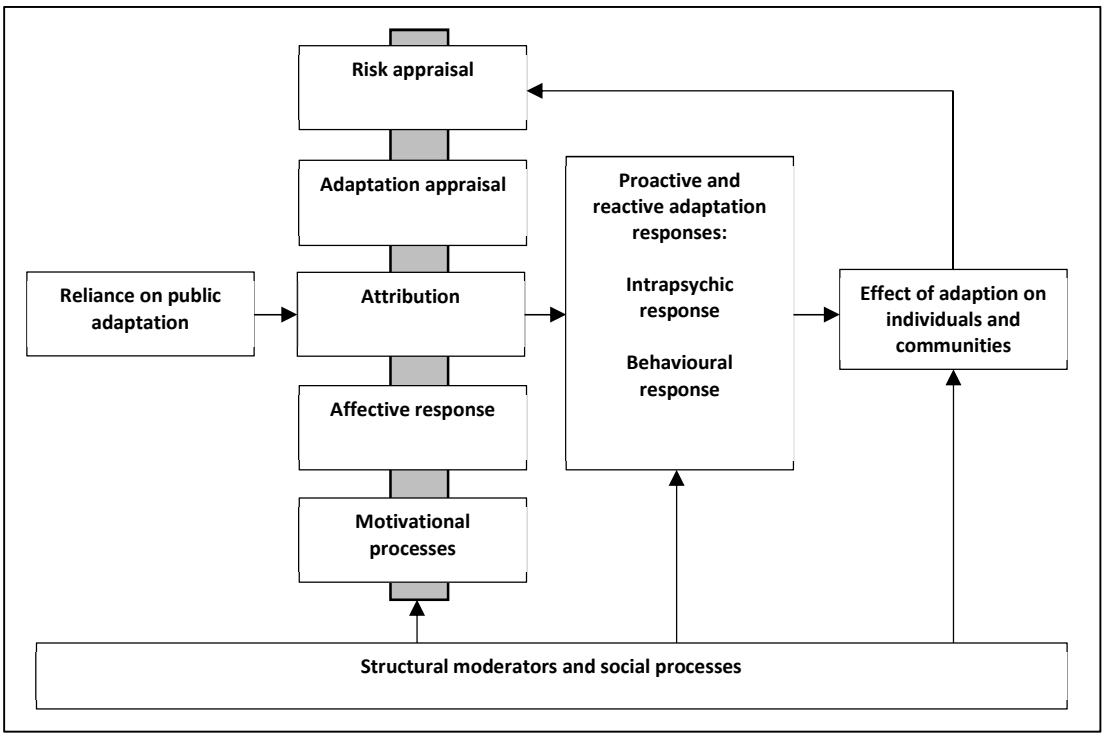

Figure 2.3: Simplified and adapted version of the APA's model of individual coping to with climate change (Swim et al. 2009)

The APA model also acknowledges that individual engagement with adaptation includes affective responses (Lorenzoni et al. 2007). Research has shown that how individuals appraise information about risks is influence by affective-driven processes as much as or more so than by analytical processing (Chaiken and Trope 1999; Marx et al. 2007; Kahneman 2011). Affective processing of risk is automatic and associative and manifests itself in different emotional reactions (Loewenstein et al. 2001). Concern and fear are two affective responses to climate change that have been extensively covered in the academic literature. Feelings of concern about climate change have been found to lead to stronger risk perceptions (van der Linden 2015) as well as greater perceived self-efficacy and responsibility to take climate action (Milfont 2012). Fear can be an even stronger motivator of individual action (Tannenbaum et al. 2015) but can also lead to disengagement and denial (Nerlich and Jaspal 2014).

Furthermore, according to the APA, individual engagement with climate change is also influenced by motivational processes. Environmental stress and coping models, such as the

PMT, assume that risk perceptions will motivate individuals to take action to protect themselves (Rogers 1983). Research however has highlighted that there are several other motivational systems that can lead to different perceptions and responses to environmental risks (Slovic 1987; Reser and Smithson 1988; Slimak and Dietz 2006). These differences can be explained by what has been called motivated reasoning – the systematic bias that occurs when individuals process information that favours pre-existing values, beliefs and attitudes (Lodge and Taber 2013).

There is ample evidence of motivated reasoning and the influence of human values on public perceptions of climate change and support for climate policy (Corner et al. 2014). Drawing on earlier work on the cultural theory of risk (Douglas and Wildavsky 1983), Kahan et al. (2011) argue that people's opinion on the scientific consensus around environmental risks such as climate change is based on what they call cultural cognition – the tendency of individuals to form risk perceptions that are congenial to the worldviews and values they share with others and that define their social identity. Research has shown that worldviews (Goebbert et al. 2012), political beliefs (Campbell and Kay 2014) and cultural cognition (Kahan et al. 2012) can help explain the polarised debate about climate change mitigation.

While political ideology (Akerlof et al. 2016) and cultural worldviews (McNeeley and Lazrus 2014) have also been shown to influence public opinion about adaptation policies, research on the effect of motivated reasoning on individual engagement with adaptation has focused more on the influence of evaluations of what is perceived to be at risk from climate change (Corner et al. 2014). O'Brien and Wolf (2010) put forward a values-based approach to adaptation which posits that how individuals will adapt to climate change hinges on what people consider to be legitimate and effective adaptation and what they perceive to be worth preserving and achieving through adaptation policy. In their study on forest managers in Canada, Oakes et al. (2016) found that adaptation to climate change-induced die-back of forests was driven by intangible values connected to forests and place attachment.

Taken together, the APA model suggests that risk appraisal, adaptation appraisal, attribution of direct and mediated experience of climate change, affective responses and motivational processes lead to two different types of adaptive response. Adaptation can be either reactive or proactive, and either intrapsychic or behavioural. Consistent with the literature on climate change adaptation (Smit and Wandel 2006), reactive responses are made after an event has occurred, whereas proactive responses are made in anticipation of an event (Aspinwall and

Taylor 1997). As in the MPACC, intrapsychic responses include adaptation intentions as well as avoidant cognitive maladaptation. Behavioural responses can include personal action to adapt to the impacts of climate change, but also seeking information and social support. The APA model also highlights, like the MPACC, that individual adaptation is moderated by structural moderators that shape people's objective adaptive capacity, and social processes that amplify or attenuate climate change risks.

In following the social amplification of risk framework (Kasperson et al. 1988) and the theory of social learning (Bandura 1977b), the APA model also assumes that how individuals adapt to climate change will affect how other individuals and communities adapt; and that their actions will feed back into personal risk appraisal, coping appraisal, affective responses, attributions and motivations. Thus, how individuals adapt forms part of a perpetual process of societal adaptation to climate change (Wolf and Moser 2011).

2.3 Climate change communication for adaptation

Climate change communication has become an established field of research in the past two decades, moving it from the fringes into the mainstream of social science on climate change (Nerlich et al. 2010; Pearce et al. 2015; Moser 2016). The potential for communication interventions to promote individual and collective action on mitigation (CRED 2009) and adaptation (Wirth et al. 2014) is now widely acknowledged by civil society and policymakers. Unsurprisingly, communicating scientific information to non-specialists in an effective, consistent and engaging manner is a key concern of the upcoming Sixth Assessment Report (AR6) from the IPCC (2017).

As the introduction to this thesis notes, climate change communication can be broadly defined as explicit efforts to promote individual or collective awareness, deliberation and action about mitigation or adaptation (Johnson 2012). This broad definition encapsulates numerous approaches that have been developed ranging from advertising campaigns to films, as well as more participatory and informal activities (Markowitz and Guckian 2018). Compared to communication for mitigation, which generally targets individual, collective and political change to reduce emissions (Moser 2016), most communication for adaptation has focused on helping individuals and communities to recognise and act on the local impacts of climate change (Moser 2014). This approach to adaptation communication largely follows the common framing of adaptation as a local issue, as opposed to mitigation as a global issue (Eriksen et al. 2015).

Adaptation communication in the context of communication science

Research on communication is a multidisciplinary and disparate field characterised by a lack of consensus on a general theory or approach (Littlejohn and Foss 2008). Luhmann (1989) for example frames all social interaction, including power relations and economic transactions, as communication and emphasises that communication in society is a process of continuous adaptation to either the target audience's needs or a common conceptualisation of a problem. The social amplification of risk theory follows a narrower definition of communication as the transmission and generation of social signals, meaning information or social cues from informal personal networks or the media (Kasperson et al. 1988). The idea that communication is a social process in which individuals are both receivers and creators of social signals reflects the paradigm shift in communication science from a linear, transmission-orientated concept of communication in which individuals receive and decode information (Shannon and Weaver 1975) to a deliberation-orientated model that conceptualises communication as "a constitutive process that produces and reproduces shared meanings" (Craig 1999, p. 125).

While both approaches to communication are present in the literature on climate change communication (Ballantyne 2016), communication for adaptation originates from transmission-orientated approaches to risk communication (Heinrichs 2010). A review of 278 adaptation communication formats by Wirth et al. (2014) showed that most communication interventions were websites, printed materials or mass media, and that participatory formats such as workshops were the exception to the rule. In a similar vein to the findings on environmental communication (Cox 2007), adaptation communication is often understood as a crisis discipline with an instrumentalist approach to communication focused on compelling messages (Russill and Nyssa 2009). The underlying assumption behind most communication interventions about risk, including climate change, is that humans do not act on a problem because they lack the correct information on the likelihood of its occurrence, its severity, its proximity and coping options (Morgan et al. 2002; Johnson 2012).

The notion that the public lacks knowledge and needs to be educated and persuaded is the rationale behind transmission-orientated science communication, which is based on the information deficit model of public understanding of science (Royal Society 1985). Applied to the context of climate change, the information deficit model assumes that it is the job of science communicators to convince people about the scientific consensus on climate change

in order to achieve intrapsychic and behavioural change (Cook et al. 2013; Pearce et al. 2015). Based on this premise, van der Linden and colleagues have developed the gateway belief model and provided evidence that informing people about the scientific consensus about climate change is compelling enough to correct cognitive biases (van der Linden et al. 2015) and overcome the influence of motivated reasoning (van der Linden et al. 2019).

However, the assumption that bounded rationality can explain lack of public concern about climate change and that providing individuals with more information can overcome the effects of worldviews and political beliefs is a matter of intense scientific debate (Kahan and Carpenter 2017; van der Linden et al. 2017). In one of the most widely cited studies on the subject, Kahan et al. (2012) found that people who score highest on tests known to predict resistance to bounded rationality – individuals with high levels of science literacy – had the most polarised views on climate change due to their personal worldviews and political beliefs. Similarly, research by Kerr and Wilson (2018) has shown that simply providing scientific information about climate change cannot overcome the influence of politically motivated reasoning. Based on this and other research, the US National Academy of Sciences (NAS 2017) concluded that it is not clear that communicating scientific information can change people's beliefs and attitudes about an issue, and that communicating scientific consensus may even contribute to the polarisation of public opinion about science.

Nonetheless, several factors speak against a blanket rejection of the information-deficit model in the context of climate change communication for adaptation. First, while there is ample evidence that worldviews and political ideology are a key barrier to public engagement in the USA (Palm et al. 2017) and the UK (Clements 2012), motivated reasoning appears to have a lesser effect on individual engagement with climate change in other countries and contexts. Based on a study of 22 European countries, Poortinga et al. (2019) found that while present in every country, the effects of worldviews and political ideology differed significantly between different regions of the continent. The same study also found no evidence of the connection between science literacy and polarised opinion on climate change that had been observed in the USA (Kahan et al. 2012). Instead, it found that respondents with high levels of education were generally more concerned about climate change, perceived more negative impacts and were less likely to be sceptical about attributing extreme events to climate change (Poortinga et al. 2019).

Second, while many studies have evaluated the influence of motivated reasoning on public belief in climate change (Poortinga et al. 2011) and support for mitigation (Campbell and Kay 2014; Kerr and Wilson 2018), there is a lack of knowledge on how worldviews on and beliefs about climate change affect attitudes to adaptation (Taylor et al. 2014). In their study on sea level rise in the USA, Akerlof et al. (2016) found that people with hierarchical or individualistic worldviews had a lower level of risk perception than those with egalitarian or communitarian views. However, the same study also found that the influence of worldviews was less important when participants were asked about the perception of risk to one's own home or property. This supports earlier research that has shown that cultural influences on perceptions of climate risks vary depending on the geographic scale under consideration (Ruddell et al. 2012). Similarly, the effect of climate scepticism on individual views on adaptation may be dependent on the kind of risk. Based on a review of the literature, Taylor et al. (2014) conclude that disbelief about the reality of climate change will have a smaller impact on willingness to proactively adopt protection measures and support adaptation policy if climate change impacts are familiar and more immediate.

Third, research also suggests that having specific knowledge about climate change can increase individual engagement with the subject even after accounting for personal values and political beliefs. A survey study of 119 countries by Lee et al. (2015) showed that climate literacy – personal understanding of the anthropogenic causes of climate change – is the single biggest predictor of climate change risk perception worldwide. In a three-year panel study of New Zealanders, Milfont (2012) showed that higher levels of climate-related knowledge increased climate change concern, which in turn translated into greater subjective environmental responsibility. Research on the general public in Australia also found that people who had greater knowledge of the causes of climate change were more willing to accept that climate change is occurring, and that climate literacy with regard to knowledge of causes attenuated the negative relationship between ideology and belief that climate change exists (Guy et al. 2014).

Fourth, even though knowledge may not be enough to drive individual engagement with adaptation, knowledge deficit continues to be a key adaptation constraint (Klein et al. 2014). Based on a review of adaptation research and practice, Klein and Juhola (2014) conclude that there are knowledge-related bottlenecks in the uptake and use of climate science. Among the most important of these are: that theoretical concepts of adaptation that do not match

with decision maker's "reality"; uncertainty about climate change impacts; a mismatch between the local scale on which many decision makers operate and the global/regional scale of climate models; a gap between decision makers' need to manage climate variability and the medium- to long-term perspective of adaptation research; and a lack of recognition of stakeholders' other priorities. Thus, the extent to which knowledge constrains or enables adaptation is dependent on how that knowledge is developed, shared and used to achieve the desired adaptation objectives (Klein et al. 2014).

Multiple reviews of the literature have concluded that transmission-orientated communication based on the information deficit model has limitations in promoting deeper public understanding of and engagement with knowledge about the causes and impacts of climate change (Gifford et al. 2011; Roeser 2012; Moser 2014). Johnson (2012) argues that persistent public indifference to or denial of climate change can partly be blamed on climate change communicators' adherence to persuasion, and that they should instead focus more on deliberation. Pearce et al. (2015) noted a shift in the research field from deficit model-driven unidirectional communication to deliberative communication. A more recent review by Markowitz and Guckian (2018) suggests that this trend is continuing. Based on research on participatory communication about different climatic risks and cultural contexts (Paton and Fairbairn-Dunlop 2010; Innocenti and Albrito 2011; Stein and Moser 2014), Moser concludes that "deliberative processes can open minds, deepen understanding, foster empathy, change attitudes, and increase receptivity to policy alternatives whereas not nearly as much impact could be achieved by simply transmitting Information" (2016, p. 353).

Before moving on to discuss the various communication techniques and strategies that have been suggested to promote individual engagement with climate change adaptation, it is necessary to comment on the limitations of communication in leading to behavioural change. There is a wealth of evidence for the so-called climate awareness-action gap – the disconnect between people's knowledge and concerns about climate change and their climate-relevant behaviour (Moser 2010). As discussed above, motivated reasoning driven by worldviews, values and cultural cognition has been cited as one reason why people interpret knowledge in a way that supports their pre-existing values, beliefs and behavioural patterns (Kahan et al. 2012; Campbell and Kay 2014). Another reason why a single communication intervention might fail to result in individual action is that people receive information about climate change from different sources with competing messages, which influences personal

perceptions and intentions to change behaviour (Arlt et al. 2011; André et al. 2017). Furthermore, as the various models of intrapsychic and behavioural change presented in the previous section highlight, individual climate action is constrained by social, economic, institutional and cultural barriers (Adger et al. 2009; Moser and Ekstrom 2010).

Communication techniques and strategies for promoting engagement with adaptation

As with transmission and deliberative approaches, communication methods for promoting engagement with adaptation can be broadly divided into framing and content-focused techniques and process-orientated strategies (Pearce et al. 2015). Framing and content-focused communication techniques focus on the framing of climate change and the targeting and tailoring of information to specific audiences (Morton et al. 2011; Bostrom et al. 2013). Process-orientated strategies involve using participatory methods to engage lay audiences and climate scientists in mutual learning, deliberation and joint development of meaningful knowledge (Larsen et al. 2012). This division, however, does not mean that messaging and content are of no concern to deliberative communication, or that participatory processes cannot be part of a transmission-orientated approach to climate change communication (Ballantyne 2016). Rather, communicators can combine different approaches, techniques and strategies depending on the target audience (Wibeck 2013).

Framing involves the selection and refinement of frames that refer to a central organising idea or storyline, which provides meaning to an unfolding series of events (Gamson and Modigliani 1987, p. 143) that can be used to shape public opinion on and understanding of an issue (Scheufele 1999). Entman offers a detailed description of how frames can shape how individuals interpret new events and experiences: "To frame is to select some aspects of a perceived reality and make them more salient in a communicating text, in such a way as to promote a particular problem definition, causal interpretation, moral evaluation, and/or treatment recommendation" (Entman and Rojecki 1993, p. 52). Unsurprisingly, climate change has been framed in many ways by media outlets, politicians, NGOs and other actors with different objectives with regard to the desired effect on people's understanding and action (Bryner 2008; Pralle and Boscarino 2011; Painter 2013). Dewulf (2013) found that in policy debates about the issue, adaptation is usually framed as the opposite of mitigation, as a technical rather than a wicked problem[1] and as a security issue. Similarly, adaptation has

[1] The term wicked problem was coined by Rittel and Webber (1973) to define problems that are hard to define because the formulation of the problem is the problem. Adaptation has been framed as

been framed in Swedish politics as a local issue that carries economic risk and can be addressed by policy-driven planning and existing policy measurers (Juhola et al. 2011).

In acknowledgement of the importance of framing in shaping individual perceptions and actions, several studies have tested the influence of framing climate change as proximate on individual perceptions, behavioural intentions and policy support (Brügger et al. 2015). Proximising climate change is expected to reduce the psychological distance between the issue and individuals who should act to mitigate it or who are vulnerable to its impacts (Elam and Bertilsson 2003; Singh et al. 2017) by making the consequences of climate change more salient (Leviston et al. 2014) and personally relevant (Scannell and Gifford 2013). Moreover, proximising climate change is believed to increase levels of emotional concern (Weber 2006), perceptions of personal vulnerability (Scannell and Gifford 2013), behavioural intentions (Reser et al. 2014) and support for adaptation policy (Singh et al. 2017).

Experimental studies have supported and rejected the assumption that proximising climate change impacts reduces psychological distance and increases personal engagement. While Wiest et al. (2015) demonstrated that local frames increased personal perceptions of the severity of climate change impacts, research by Spence and Pidgeon (2010) found the opposite effect. Findings by Schuldt et al. (2011) suggest that the difference in the outcomes of proximation can be explained by motivated reasoning and the influence of worldviews and political ideology. However, a study by Chu and Yang (2018) showed that the influence of political ideology on climate change perception was reduced when climate change impact was portrayed as spatially close and familiar, as opposed to spatially distant and novel. Their findings support the argument made by Sjöberg (2000) that motivated reasoning is a poor explanation of how individuals perceive risk that might have adverse personal consequences. In sum, proximation of climate change can work if what is framed to be at proximal risk is of importance to people and if they believe that any possible adaptation actions will be acceptable, feasible and effective (Brügger et al. 2015).

Another way of framing climate change is in terms of losses or gains. As noted in Chapter 1, climate change has been framed as a risk as well as an economic opportunity for the Swedish forest sector (Ulmanen et al. 2015). Again, Wiest et al. (2015) and Spence and Pidgeon (2010)

wicked, because vulnerability to climate change impacts is the consequences of other problems, it lacks a well-structured policy domain, and its framing and solutions are highlight contested and interconnected with other problems (Termeer et al. 2013).

come to different conclusions. The former finds no effect of either framing on risk perception and behavioural intentions, while the latter suggests that gain frames are superior to loss frames in increasing the perceived severity of climate change impacts. Morten et al. (2011) also found that highlighting potential losses from climate change combined with the high levels of uncertainty about impacts decreased individual motivation to adopt pro-environmental behaviours. The negative influence of loss framing on risk perception and behavioural intentions can be explained by research that has shown that appeals to fear can have a debilitating effect on personal engagement with climate change (O'Neill and Nicholson-Cole 2009).

As noted above, adaptation to climate change continues to be limited by a lack of knowledge that audiences find relevant and actionable (Klein et al. 2014). To bridge this knowledge gap, Bostrom et al. (2013) argue for better targeting and tailoring of climate change communication. Targeting and tailoring are well-established practices in social marketing. They involve audience segmentation and customising communication channels and information to fit audiences' needs and social contexts (McKenzie-Mohr et al. 2012). The need for more targeted and tailored information and knowledge has also been recognised in the literature on climate change adaptation, which is reflective of the growing interest in developing climate services (Hewitt et al. 2012).

Audience segmentation forms the basis for targeted communications interventions. It involves the identification of a specific subpopulation to receive communications based on their like-mindedness (Maibach et al. 2011), carbon-intensive behaviour (Abrahamse et al. 2007), exposure or vulnerability to climate change impacts (Arunrat et al. 2017) or community of practice, such as forest managers (Bowers et al. 2016). Audience segmentation also involves identifying the values, concerns and needs that motivate audience members and what they believe and already know, or perceive to know, about climate change and measurers that can help reduce its impact (Markowitz and Guckian 2018). Knowledge about an audience's worldview or level of concern about climate change can be useful when developing framing and messaging (Hine et al. 2014). Similarly, knowing what people already believe about climate change can help communicators identify easily understood words and concepts, correct common misconceptions and build appropriate heuristic models where they are lacking (Bruine de Bruin and Bostrom 2013).

After audiences have been identified, information is tailored to fit their needs and decision-making contexts (Bostrom et al. 2013). The tailoring of information in the area of adaptation commonly involves downscaling earth system models to help authorities, communities or individuals understand and adjust to the local impacts of climate change (van den Hurk et al. 2018). Progress has been made in recent years on developing sophisticated interactive visualisation tools that assist individuals such as homeowners (Glaas et al. 2017) or forest managers (Rammer et al. 2014) in understanding their exposure to climate change risks and adaptation options. Linking back to Grothmann and Patt's (2005) concept of perceived adaptive capacity, tailored information should highlight solutions to climate change to promote belief in the effectiveness of adaptation measures, their benefits and personal ability to implement and manage them (Moser 2014).

However, even if information is tailored to fit target audiences, the uncertainty of climate projections is still a big barrier to communication that engages individuals with climate change adaptation (Moser 2014). Dessai and Hulme (2004) distinguish between epistemic, stochastic and human reflexive uncertainty. Epistemic uncertainty results from incomplete knowledge of climate parameters; stochastic uncertainty derives from complex processes for which only statements about probable outcomes are possible; and human reflexive uncertainty is a product of the fact that climate models are driven by assumptions about social processes which are themselves affected by climate models. The first two types of uncertainty are usually represented by probability distributions of changes in climate, weather or extreme events (Böttinger and Röber 2019). Human reflexive uncertainty is represented by scenarios that include assumptions about future emissions, economic development or adaptation action (Kebede et al. 2018). Downscaling global climate models introduces another source of uncertainty for communicating future projections of local climate change impacts (Ekström et al. 2015). Thus, the inherent uncertainty of climate science limits the communication technique suggested by the gateway belief model of providing the public with consensual information because scenarios about climate change impacts and human adaptation necessarily vary depending on the scale, climate-related parameters and future assumptions about social development (Pidgeon and Fischhoff 2011).

Research has shown that perceived uncertainty has a considerable influence on people's judgements and behaviour in relation to climate change. Scepticism about climate change has been linked to media representations of climate change as controversial and uncertain

(Boykoff and Boykoff 2004). Even if people believe in the reality of climate change, Weber (2010) argues that perceived uncertainty will lead most people to discount its future risks and costs. This argument is supported by the literature on bounded rationality, which has shown that people are generally averse to taking action based on information that they perceive as uncertain (van Dijk and Zeelenberg 2003).

However, research also suggests that there are better ways to frame and customise information about the uncertainty of climate change projections. Based on a review of the literature, Moser (2016) suggests that arguing in favour of climate action *because* of the level of uncertainty is an effective way of countering people's justifications for inaction linked to uncertainty. Morten et al. (2011) showed that perceptions of uncertainty are linked to feelings of self-efficacy, suggesting that messages about uncertainty should be combined with messages that highlight what people themselves can do to address climate change. Others have suggested that communicators should be more transparent about uncertainty in order to address misconceptions and mistrust of climate science (Pearce et al. 2015; Markowitz and Guckian 2018). Visschers (2018) also highlights the importance of trust, suggesting that to increase public concern about climate change it will be necessary to address public perceptions of the ambiguity of climate science.

Trust in climate science has long been a subject of research about public opinion about climate change (Leiserowitz et al. 2013) and adaptation (Moser and Ekstrom 2010). Given the complexity of scientific knowledge and their lack of expertise to check its soundness, Collins and Evans (2007) argue that lay people must make social judgements on who should be trusted rather than scientific judgements about what should be trusted. Unfortunately, mistrust of climate science has been growing recently. A review of public opinion about climate change showed a proliferation of public doubt and scepticism about the reality and severity of climate change since the late 2000s and early 2010s (Capstick et al. 2015). Recent studies have also shown that the link between knowledge and concern about climate change is dependent on trust (Malka et al. 2009), and that trust influences the relationship between the perceived motives of climate scientists and acceptance of climate change messages (Rabinovich et al. 2012). Thus, restoring public trust in science has been called the latest paradigm in science communication (Wynne 2006).

Most of the techniques for building trust in climate science suggested in the literature focus on improving public perceptions of climate scientists. Based on experience in environmental

risk communication, Peters et al. (1997) suggested that trust in scientists derives from perceived levels of expertise, openness and honesty, and concern and care. However, efforts to build trust are hampered by the fact that like other controversial scientific issues, mistrust in climate change and science depends on personal values and political ideology (Kahan et al. 2011). Whitmarsh (2011) found that in the UK, scepticism about climate change is determined by people's environmental and political values. This supports earlier research that showed that trust in climate science is strongly affected by motivated reasoning (Malka et al. 2009). In his controversial book, *An Honest Broker*, Pielke (2007) makes the point that instead of advocating for specific solutions that could be perceived as favouring a certain political ideology, scientists should be more interested in building relationships with their audience. To achieve this, Goodwin and Dahlstrom (2014) suggest that climate scientists and communicators should make themselves more vulnerable by engaging with doubtful and dismissive audiences and committing themselves to a relationship through which they can prove their trustworthiness.

Building trust and relationships between climate scientists and target audiences is the key objective of the deliberation-orientated approach to climate change communication (Moser 2016). To achieve this, deliberative communication uses participatory strategies that enable joint definition of problems and solutions (Ballantyne 2016). Deliberative communication for adaptation also draws on experiences with adaptive co-management of natural resources (Armitage et al. 2008), participatory integrative assessment of climate impacts and vulnerability (Cohen and Neale 2006) and public engagement in science communication (Wynne 2006). As noted in Chapter 1, this thesis uses the concept of science-based stakeholder dialogues, which has as its objective facilitating two-way communication between climate scientists/communicators and audiences to promote analytical and interpersonal learning (Welp et al. 2006a).

Based on a review of the literature, Moser (2016) believes that there are grounds for optimism that participatory communication strategies can achieve their goal of deepening public understanding, fostering empathy and increasing support for climate policies. As mentioned above, open discussions with climate scientists can improve people's understanding of the inherent uncertainty of climate change projections and reduce cognitive discounting of future impacts (Pearce et al. 2015). Research also suggests that deliberative communication can overcome the shortcomings of transmission-orientated

communication by appealing to more than just analytical thinking and by weakening the influence of motivated reasoning. Marx et al. (2007) found that sharing vicarious experiences of climate change in group discussions enabled experiential as well as emotional processing of climate change forecasts. In their study on sea level rise in the USA, Akerlof et al. (2016) showed that deliberations with climate scientists increased topic knowledge and problem identification, as well as concern about impacts among participants with a worldview that predisposed them to lower risk perceptions. Furthermore, the outcomes of deliberation can also be used to inform more content-orientated approaches to climate change communication (Johnson 2012).

2.4 Implications for the thesis

This section summarises the literature on individual engagement with adaptation, intrapsychic behavioural models, and adaptation communication, and discusses the implications for this thesis in relation to its overarching research question and its aims.

As stated in Chapter 1, this thesis asks if climate change communication can promote individual engagement with adaptation. To assess the effect of climate change communication on individual engagement, it is necessary to understand the scope and drivers of engagement. Based on the literature reviewed in this chapter, individual engagement with adaptation can be understood as a personal state that concurrently comprises cognitive, affective and behavioural aspects (Lorenzoni et al. 2007), and affects how individuals perceive and respond to climate change risks (Moser and Ekstrom 2010). Based on models of intrapsychic and behavioural change that were discussed in this chapter, including the MPACC by Grothmann and Patt (2005) and the model of individual adaptation to climate change by APA (Swim et al. 2009), it can be concluded that individual engagement with adaptation is driven by intrapsychic conditions and social processes.

Intrapsychic conditions include cognitive appraisal of climate change risks and adaptation options (Grothmann and Patt 2005). Risk appraisal involves an assessment of severity, and of exposure and resilience to climate change impacts. Adaptation appraisal comprises personal assessment of the efficacy of adaptation measures, as well as self-efficacy to manage adaptation. Risk and adaptation appraisals are influenced by personal experience of extreme events (Whitmarsh 2008) and bounded rationality (Weber 2017). Beyond cognitive thinking, intrapsychic conditions also include affective responses (Roeser 2012), attribution of personal experiences of extreme events and changing weather conditions to climate change

(Blennow et al. 2012) and motivated reasoning (Kahan et al. 2012). Intrapsychic conditions can lead to intrapsychic responses, behavioural intentions and actual behaviour change that can be either adaptive or maladaptive (Swim et al. 2009). Social processes shape how individuals construct (Pettenger 2007), amplify (Renn 2011) and learn about (Reed et al. 2010) climate change adaptation. Social discourses about climate change, including science communication, can lead people to change their perceptions and lead to greater engagement with adaptation (Swim et al. 2009). Given its complexity and uncertainty, personal trust in climate science is another important influence on individual engagement with adaptation (Goodwin and Dahlstrom 2014).

The chapter also found that climate change communication for adaptation belongs to the broader field of risk and science communication (Heinrichs 2010). Two different approaches to adaptation communication have been identified in the literature (Ballantyne 2016). First, the transmission-based approach considers knowledge deficit to be the key barrier to individual engagement with adaptation, which can be overcome using persuasive framing and content-focused techniques (Bostrom et al. 2013). Second, the deliberation-orientated approach is based on participatory strategies to promote analytical as well as intrapersonal learning (Welp et al. 2006a). Both communication approaches can be combined and have their strengths and weakness in reducing the perceived distance of climate change (Marx et al. 2007), increasing self-efficacy beliefs (Morton et al. 2011), overcoming the influence of motivated reasoning (van der Linden et al. 2019), building trust in climate science (Goodwin and Dahlstrom 2014) and promoting behavioural intentions and adaptive action (Moser 2014).

In conclusion, the discussion of the literature has identified two research needs: First, there is a need for actor-based research on individual adaptation to test insights from models of intrapsychic and behavioural change. This research should examine if intrapsychic conditions identified in these models – individual appraisal of global as well as local climate-related risk; personal self-efficacy beliefs; assessments of adaptation options; emotional concern about climate change impacts; trust in climate science; attribution of personal experience to climate change; and personal intentions and actions to adapt to climate change – can explain individual adaptation to climate change. This research need is expressed in the first research aim and addressed in Chapters 3 and 4 of the thesis.

Second, the literature also suggests that measuring the effect of climate change communication on individual engagement with adaptation requires examining changes in intrapsychic conditions and intrapsychic responses. This research would help scientists and practitioners understand if, and how, different approaches to climate change communication can help people overcome cognitive barriers and motivated reasoning to become more engaged with adaptation over the short- and long-term. The need for better research about climate change communication is reflected in the second, third and fourth research aim of the thesis and addressed in Chapters 4 to 6.

Furthermore, research about climate change communication also needs to acknowledge the context in which communication takes place. Studies about the effect of communication on individual engagement with adaptation must consider the influences of social institutions, socio-economic conditions and the discourse about climate change. Thus, findings of the thesis are discussed in the context of the Swedish forest sector. In addition, Chapter 7 presents a model of climate change communication to promote individual engagement with adaption in the context of the Swedish forest sector.

Chapter 3: The relative importance of subjective and structural factors for individual adaptation to climate change by forest owners in Sweden

3.1 Introduction

As the impacts of climate change become more tangible and severe, interest in how and why individuals adapt to them is growing (Tam and McDaniels 2013). In the case of forest owners, evidence exists that some of them in both Europe and elsewhere are starting to consider adaptive actions (Keskitalo et al. 2011b; Blennow 2012). The scientific understanding about favourable conditions of individual engagement with adaptation, however, remains obscure as research points in different directions. Much of the contemporary scientific literature about climate change adaptation focuses on structural factors that determine the capacity of society and its institutions to adapt to climate change impacts (Brooks et al. 2005; Füssel and Klein 2006; Tinch et al. 2015). These studies examine the availability and accessibility of economic resources, knowledge or legislation to explain whether, how and why adaptation takes place. By following this determinants-based approach, individual adaptation can be understood as part of "(…) local or community-based adjustments to deal with changing conditions within the constraints of the broader economic–social–political arrangements" (Smit and Wandel 2006, p. 289). This suggests that individuals are more likely to adapt to climate change if they have the ability and access to resources to anticipate and respond to climatic risk and if socio-economic conditions are favourable.

A growing field of research, however, has argued that the structural approach is limited in its ability to explain adaptive capacity and action by individuals (Narayan 2005; Adger et al. 2009; Kuruppu and Liverman 2011). This literature focusses instead on subjective factors that explain individuals' perceptions, intentions and actions for climate change adaptation (Grothmann and Patt 2005; Lorenzoni et al. 2007; O'Brien and Wolf 2010). In its last assessment report, the IPCC acknowledges that how individuals adapt to climate change is contingent on their perception of climatic risks as well as their values and objectives (IPCC 2014a). This suggests that the process of individual adaptation is shaped by cognitive, affective and behavioural factors (Lorenzoni et al. 2007). In this study, we aim to develop an empirically grounded understanding of individual adaptation to climate change by assessing

and comparing the influence of structural and subjective factors on individuals' intention to adapt to climate change and their perception of the need to adapt. In the next section, we will review the contemporary literature on the factors behind individual adaptation and develop assumptions about their relevance and effect. In the following section, we describe the case study and how we operationalised, collected and analysed our empirical data. We then present results from a national survey with forest owners in Sweden. The final section will discuss the findings and draw conclusions for climate change communication.

3.2 Factors shaping individual adaption to climate change adaptation

Over the last two decades, several approaches to individual adaptation to climate change have been developed, drawing from diverse disciplines including behavioural science, psychology, sociology and anthropology (Pelling and High 2005; Fazey et al. 2007). A significant amount of empirical knowledge now exists that shows that socio-cultural, cognitive and experiential factors can explain how individuals perceive and respond to climate change (Patt and Schroter 2008; O'Brien 2009; Frank et al. 2011). These factors influence the different stages of the adaptation process, starting with the assessment of climate change risks, followed by the appraisal of adaptation options and leading to the implementation, monitoring and improvement of adaptive measures (Moser and Ekstrom 2010). One of the key challenges of research has been to account for the interplay between structural and subjective factors for individual adaptation (O'Brien and Wolf 2010).

Grothmann and Patt (2005) propose an analytical model that includes cognitive, experiential and structural factors to explain why and how individuals adapt to climate change. The model builds on the Protection motivation theory (Rogers 1983; Milne et al. 2000) and suggests that the process of individual adaptation to climate change relies on how individuals perceive climate change risks and how they appraise adaptation actions. The model also acknowledges that individual risk and adaptation judgements are shaped by an individual's objective adaptive capacity and the social discourse surrounding climate change (see Figure 2.1).

The literature suggests that an individual's objective capacity can be measured in terms of personal access to relevant resources (Keskitalo et al. 2011a). To appropriately understand adaptive capacity, one must also consider an individual's exposure and vulnerability to climatic risks (Smit and Wandel 2006). Applied to the context of Swedish forestry, we can expect that forest owners with a higher income, larger forest property and dependency on

income from forestry are more likely to consider climate change adaptation as an urgent issue and plan to take risk-mitigating measurers.

The literature also provides evidence that cognitive factors such as personal beliefs about climate change are another set of important factors to understand individual adaptation (O'Brien and Wolf 2010; Wolf et al. 2013). First, trust in climate science has been found to have considerable mediating influence on how people make sense of, and act on, scientific information about climate change (Moser 2010). Second, personal belief in having experienced climate change – attribution of personal experience to climate change – has been found to be one of the strongest drivers behind individual adaptation (Blennow et al. 2012). Trust in climate science and attribution of personal experience to climate change have also been shown to be the subject to social discourse about the topic which is shaped by social norms, political ideology and values-based group identities (Kahan et al. 2011).

Individual adaptation to climate change can also be explained by cognitive risk judgements. Climatic risks may be perceived as greater if they threaten something that is highly valued (Grothmann and Patt 2005), implying that people's values are crucial in shaping their perception of climate risks and adaptation needs (Wolf et al. 2013). Furthermore, the perceived proximity of climate risks is another important factor. A recent study by Brügger et al. (2015) has shown that the likelihood of individuals acting is higher if they think that climate change poses an immediate risk to something that is important to them.

The same study by Brügger et al. (2015) also highlights that another necessary condition for individuals to actions on climate change is their conviction that these actions are possible, feasible and effective. This is what Grothmann and Patt (2005) call adaptation appraisal. Perceived self-efficacy is a particularly important factor, as it directly affects a person's motivation to change behaviour (Zimmerman 2000). It also shapes personal behaviour and resilience, as individuals with a stronger sense of self-efficacy are likelier to evaluate and adjust their behaviour in response to changing conditions (Bandura 2001).

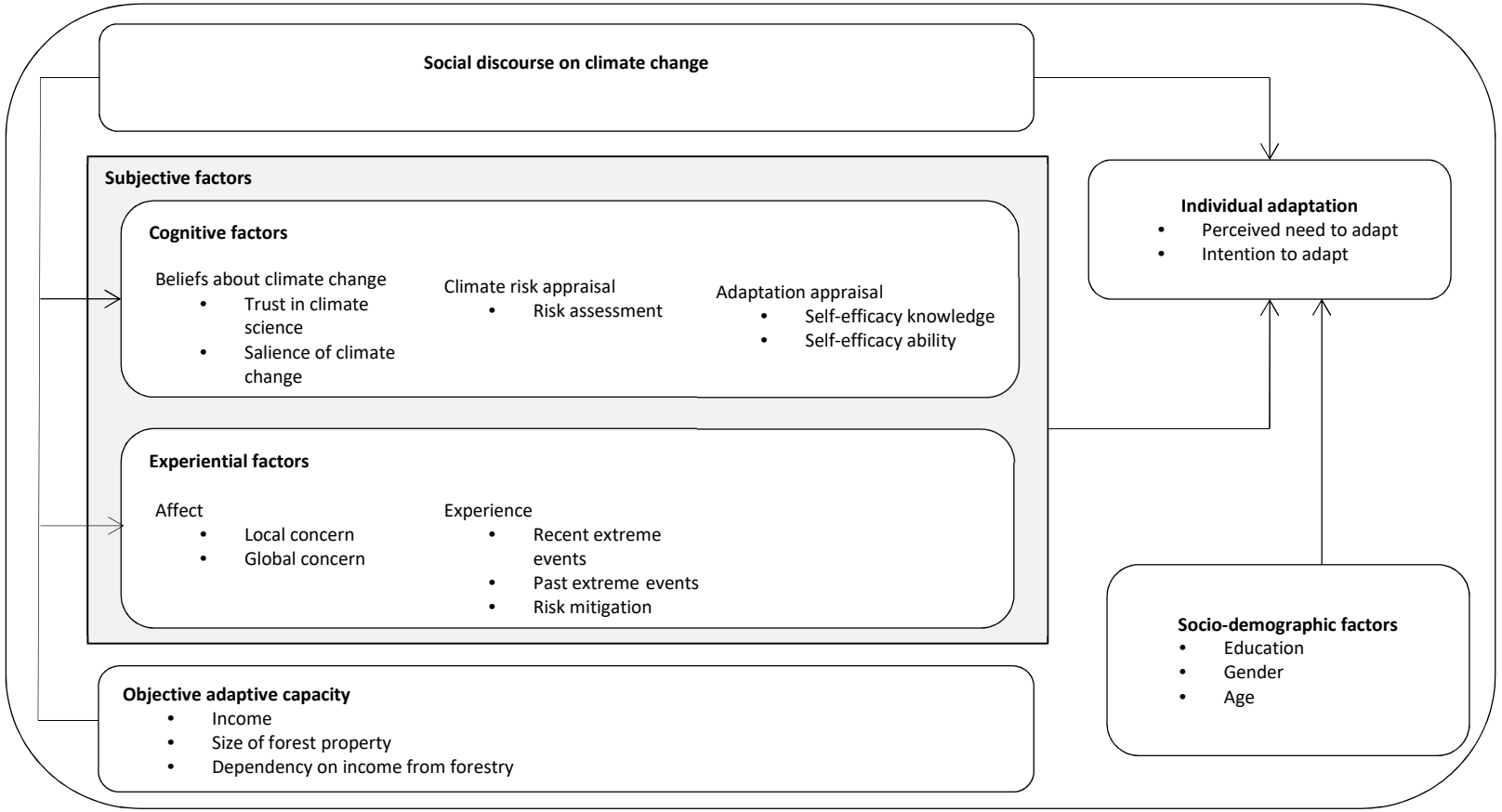

Figure 3.1: Conceptual and analytical model of individual adaptation to climate change (based on Grothmann and Patt 2005 and van der Linden 2015)

Experiences with extreme events may also play an important, albeit indirect role for individual engagement with adaptation. Studies have suggested that people who experienced flooding show greater awareness about climate change (Spence et al. 2011) and are better prepared for future flooding events (Kreibich et al. 2011). However, the effect of personal experiences with extreme events on climate awareness and action is contingent on personal beliefs about personal experience with climate change (Akerlof et al. 2013). It has also been found that this influence fades over time (Kreibich et al. 2011b. Taking this into consideration, we assume that personal experience with extreme events will have no significant effect on individual adaptation.

Apart from personal experience with extreme events, affect is another type of experiential factor that can enhance climate awareness (van der Linden 2015). Its effect on individual engagement with climate change adaptation, however, is not well understood yet. Following Slovic et al. (2007) definition, affect is an evaluative feeling towards external stimuli. Amid some disagreement about the difference between affect and emotion (Sjöberg 2006), a recent study found that affect is the single most important predictor of personal climate risk perception (van der Linden 2015). Considering developing knowledge about the importance of affect, we assume that concern about climate change can help explain individual adaptation to climate change. We also expect that concern about local impacts of climate change are more important for individual adaptation than concern about its global consequences.

Lastly, there are several socio-demographic factors including level of education and gender which effect on individual adaptation is unclear. In the case of education, some research has suggested that high level of educational attainment at least in developing countries improves climate awareness (Lee et al. 2015). Research in developed countries, however, has pointed out that the more educated individuals are, the more they prefer to rely on their own interpretation and political worldviews rather than established climate science to form their opinion about climate change (Stoknes 2014). The effect of gender also seems to be in dispute with some studies showing that females tend to have higher risk perception (Brody et al. 2008) while others have shown no such effect (van der Linden 2015). In this study, we do not assume that either education or gender has an influence on individual engagement with adaptation.

Taken together, this study will test the overarching hypothesis that subjective factors are better in explaining individual adaptation than structural determinants of adaptive capacity. To test this general hypothesis, we assess several detailed hypotheses that about the factors included in Figure 3.1. Forest owners will have a stronger sense of need to adapt and are more likely to have the intention to take adaptive action if:

1) They have a high income, own large forest property or are dependent on forestry income (Hypothesis 1: Objective adaptive capacity).
2) They attribute personal experience with extreme events to climate change or have a high level of trust in climate science (Hypothesis 2: Attribution and trust).
3) They consider the risk of climate change on their forest property as high (Hypothesis 3: Climate risk appraisal).
4) They have a strong sense of self-efficacy to take adaptive actions (Hypothesis 4: Adaptation appraisal).
5) They have personal experience of extreme events (Hypothesis 5: Experience of extreme events).
6) They are concerned about the local or the global impacts of climate change (Hypothesis 6: Affect).
7) They are highly educated or female (Hypothesis 7: Socio-demographic factors)

3.3 Case study and research design

Case study

This study focuses on private, non-industrial forest owners in Sweden who own around 50 percent of the country's 28.2 million ha of forests (Swedish Forest Agency 2014). Sweden, the most forest-rich country in Europe (Forest Europe et al. 2011), is among the top three exporters of paper, pulp and sawn wood products in the world (Skogsindustrierna 2014). Climate change is expected to lead to increasing temperatures and changes in precipitation levels, although the extent of these changes varies between different emission pathways (SMHI 2014). In general, climate change is expected to have considerable implications for the forestry sector and will likely increase risk from pests and pathogens—but also to improve growing conditions (Swedish Commission on Climate and Vulnerability 2007). Although storms are not projected to increase in frequency or intensity (Nikulin et al. 2011), vulnerability to storms will increase under a changing climate due to inferior ground frost conditions during winters and generally wetter conditions (SMHI 2014).

Despite growing scientific knowledge, uncertainty about the impacts of climate change persists. For example, scientific understanding of future climate impact on spruce bark beetle is constrained by uncertainties in regional climate models (Jönsson and Bärring 2011). Uncertainties stemming from climate models also limit findings about appropriate adaptation measures (Jönsson et al. 2013). Nevertheless, climate related risk and adaptation has become a concern for at least some Swedish forest owners (Keskitalo 2011). There is also evidence that Swedish forest owners are starting to take adaptive action (Blennow 2012).

Operationalisation of dependent and independent variables

The conceptual and analytical model of this study (Figure 3.1) includes all structural and subjective factors of individual adaptation that were discussed in the previous section. These factors were turned into measurable dependent and independent variables and included in the survey in the form of statements and questions (Table 1.1). The design of the survey and many of its questions and statements were drawn from earlier research in the MOTIVE project which had assessed individual engagement among forest owners in Sweden, Germany and Portugal (Persson et al. 2011). This includes questions about personal experience with extreme events and if forest owners believed that these events have been caused by climate change. Both factors were shown by research from the MOTIVE project to have a significant effect on personal adaptation among forest owners (Blennow et al. 2012). Questions about personal experience with extreme events and attribution of these events are also included to respond to the fifth and second research hypothesis of this study.

Questions about forest owners' socio-economic properties, size of forest property and dependency on income from forestry have been gleaned from earlier research by Andersson and Gong (2010) on risk management among forest owners in Sweden. These variables were selected to test the first hypothesis and to assess the influence non-cognitive and non-experiential factors on forest owners' level of engagement with adaptation. Questions about the other variables were developed based on the broader literature on climate change communication and risk perception, including questions about self-efficacy (Swim et al 2009) and personal intention to adapt (Grothmann and Patt 2006), trust in climate science (Weber 2010) and personal concern about the global and local impacts of climate change (Roeser 2012, Tam and McDaniels 2013). These questions also help to answer the remaining research hypotheses.

This study examines two different dependent variables to measure individual adaptation to climate change—personal sense of need to adapt forest property to climate change and stated intention to take risk-mitigating actions in the coming five years. Personal sense of need to adapt is measured in responses to the statement "I think I need to take climate change into greater consideration" from strongly disagree to strongly agree on a five-point Likert scale. Intention to take risk mitigating actions in the coming five years – the second dependent variable of individual adaptation – is measured in binary responses to the statement "I plan to take risk mitigating measures to address climate change in the coming five years". Unlike the first dependent variable, the second dependent variable is a categorical variable.

Predictor variables in this study were measured on categorical, ordinal and continuous scale. Variables to measure objective adaptive capacity include income (ordinal), dependency on forestry income (ordinal) and size of forest property (continuous). Cognitive factors behind individual adaptation are split into individual belief that extreme events in the past in Sweden have at least partly been caused by climate change (ordinal) and trust in climate science (ordinal). Variables to measure cognitive factors of individual adaptation also include climate risk appraisal in terms of individuals' assessment of climate change risks (ordinal). Data on adaptation appraisal are responses by forest owners to the statement that they have enough knowledge to adapt their forests to climate change (ordinal) and that they can adapt their forest property to climate change (ordinal). Variables related to experiential factors include concern about local and global impacts of climate change (ordinal) and experiences with extreme events and risk mitigation (categorical). In addition, information about socio-economic variables – education, gender and age – is also part of the empirical data.

Data collection and analysis

Data for this study was collected with a survey of forest owners in Sweden which was conducted in the first half of 2014. The questions of the survey were developed and tested in two different pilot studies. The first pilot study consisted of a qualitative focus group interviews with forest owners in Southern Sweden. The second pilot study was a quantitative survey with 100 randomly selected forest owners. After the results of the two pilots were analysed, the final version of the survey was distributed to 3000 randomly selected forest owners. Contact information of forest owners that participated in this study was collected from databases of landowners in Sweden of the Swedish Mapping, Cadastral and Land

Registration Authority (Lantmäteriet) and the Swedish Forest Agency. All 3000 forest owners received a postal invitation letter to take part in the survey a week before they received a copy of the survey by mail. Owners were also given access to a web-based version of the survey. Three weeks after the first sent out of the survey, owners received a reminder via mail. Another three weeks later, forest owners who so far had not responded received a paper-based version of the survey, as well as access to a web-based version. The collection of surveys was closed three months after owners had received the invitation letter.

The final version of the survey consisted of a total of 55 open-ended and closed questions of which fifteen were used in this study[2]. The response rate was 28 percent resulting in 836 valid responses. Data about the total size of forest property for respondents and non-respondents came from the database of the Swedish mapping, cadastral and land registration authority. A Welch two-sample test showed that the mean property sizes of the two groups differed significantly (t test, t = 3.50, df= 1529.34, p value <.001). The average size of forest property was 60.74 ha for respondents and 48.66 ha for non-respondents, which implies that forest owners with a larger total forest property are overrepresented in study. As outlined above, the two dependent variables – perceived need to adapt and intention to take risk-mitigating measures to address climate change – were collected on an ordinal and binary scale, respectively. Thus, data analysis was limited to frequency analysis, ordinal and binary logistic regressions. To perform these regression analyses, ordinal scaled independent variables, which were all on a five-point scale, had to be recoded into binary variables. The statistical software R was used for the data analysis (R Core Team 2015).

3.4 Results

Results are presented in two different sections. The first section gives an overview about the key structural and subjective factors of individual adaption to climate change. The second section presents the results of two logistic regression models to test assumptions about the influence of the different cognitive, experiential and structural factors on individual adaptation among forest owners.

[2] Other studies that are based on other or the same questions from this survey include André et al. (2017a) and Blanco et al. (2015)

Table 3.1: Forest owners' views on climate change risks, adaptation and their socio-economic properties

Number of forest owners		**836**
Share of forest owners in percent that [1]		
a)	are concerned about climate change in relation to their forest *(Local concern)*	27.33
b)	are concerned about climate change globally (Global concern)	44.73
c)	consider risk of climate change for their forest as serious *(Risk assessment)*	27.23
d)	have taken risk mitigating measures in the past *(Experiences risk mitigation)*	84.57
e)	think that they have enough knowledge to adapt their forests to climate change *(Self-efficacy knowledge)*	20.81
f)	think that they are capable of adapting their forests to climate change *(Self-efficacy ability)*	20.06
g)	have experienced extreme events in the past ten years *(Past extreme events)*	45.10
h)	have experienced extreme events in 2013-2014 *(Recent extreme events)*	29.03
i)	believe that experienced extreme events have been caused by climate change *(Attribution)*	41.01
j)	consider climate science to be trustworthy *(Trust in climate science)*	38.97
k)	think that they need to take climate change into greater consideration *(Sense of need to adapt)*	21.53
l)	plan to take risk mitigating measures to address climate change in the coming five years *(Intention to adapt)*	38.75
Share of forest owners that are dependent on income from their forestry in percent *(Dependency on forestry income)*		12.40
Average size of owned forest in ha *(Size forest property)*		61.69
Share of forest owners with higher income in percent *(Income)*[2]		24.45
Share of forest owners with higher education in percent *(Education)*[3]		36.89
Average age *(Age)*		61.54
Share of men among forest owners in percent *(Gender)*		79.07

[1] In the case of variables a) to g), respondents were asked to reply to each of these variables on a scale from 1 to 5. Percentages shown here represent the share of forest owners that responded with 4 or 5.
[2] > 40.000 SEK per month and household
[3] University education

Forest owners' views on climate change risks and adaptation

Table 3.1 summarises findings about forest owners' views and experiences with climate change risks, adaptation and their socio-economic properties. What stands out is that forest owners are more concerned about the global consequences of climate change than its impacts on their own forest property. The data also suggests that a large majority of forest owners have experiences with risk-mitigating measurers and that almost half of them have experienced extreme events in the past ten years. In addition, almost a third of them had experienced extreme weather shortly before the survey was conducted. Notably, results from the survey also suggest that attribution of personal experience to climate change is considerable with more than two fifths of forest owners believing that personally experienced extreme events have been caused by climate change. However, most of forest owners considered climate science not to be trustworthy.

At large, results show that individual adaptation to climate change is still limited to a minority of forest owners. Only around a fifth of them have a strong sense of need to take climate change into greater consideration. However, almost 40 percent of them stated that they have the intention to take measures to mitigate risk related to climate change in the coming five years. Given that most forest owners in this study do not think that they have enough knowledge or ability to adapt to climate change, those risk-mitigating measures could be considered autonomous rather than planned adaptation (Smit and Wandel 2006).

Assessing factors of individual adaptation

Individual adaptation was measured in this study by using two different dependent variables. The first of these variables is personal sense of the need to adapt personal forest property to climate change. Table 3.2 shows results of an ordinal logistic regression model, including the level of significance and odds ratio of the different independent variables. Results show that risk assessment, belief in climate change in relation to experienced extreme events, and trust in climate science are significant factors explaining to what degree forest owners considered it necessary to adapt to climate change.

Thus, results support hypotheses two and three by showing that if forest owners considered the risk of climate change to their forest property as serious, the odds that these forest owners think that they need to adapt to climate change versus them thinking that they do not need to adapt, or that they are undecided, are combined 3.4 times greater, given that all other independent variables are held constant. The odds ratio for attribution of climate change and trust in climate science are around half of that, suggesting that the two factors have a lesser, albeit still statistically significant positive effect on individual sense of the need to adapt.

The second variable to measure individual adaptation was the stated intention to take measures to mitigate risks related to climate change in the coming five years. Table 3.3 shows the results of a binary logistic regression. The outcomes show that risk assessment, experience with risk mitigation, belief in self-efficacy related to knowledge and perceived experience with climate change are all statistically significant factors that explain forest owners' intention to take risk-mitigating measures.

Table 2.2: Ordinal regression analysis of personal sense of need to adapt

Variable	Estimate	Standard error	t value	p-value	Odds ratio
Local concern	0.36	0.29	1.39	.165	1.43
Global concern	0.29	0.21	1.42	.156	1.34
Risk assessment	1.22	0.27	4.53	<.001	3.38
Experiences risk mitigation	0.35	0.27	1.28	.199	1.42
Self-efficacy knowledge	0.00	0.30	0.01	.994	1.00
Self-efficacy ability	- 0.02	0.30	- 0.05	.956	0.98
Past extreme events	0.027	0.17	0.16	.876	1.03
Recent extreme events	- 0.12	0.18	- 0.64	.523	0.89
Attribution	0.63	0.19	3.28	.001	1.88
Trust in climate science	0.44	0.19	2.27	.023	1.55
Dependency on forestry income	0.19	0.27	0.69	.489	1.21
Size forest property	0.00	0.00	0.60	.550	1.00
Income	- 0.12	0.20	- 0.60	.545	0.88
Education	0.22	0.19	1.13	.256	1.24
Age	- 0.01	0.01	-1.15	.251	0.99
Gender	0.23	0.22	1.06	.291	1.26

318 out of 836 observations missing
Residual deviance 1361.26
AIC 1401.26

Table 3.3: Binary logistic regression analysis of stated intent to take risk mitigating measures related to climate change

Variable	Estimate	Standard error	t value	p-value	Odds ratio
Intercept	2.027	0.70	-2.88	.004	0.13
Local concern	-0.24	0.32	-0.76	.447	0.78
Global concern	0.10	0.24	0.42	.674	1.11
Risk assessment	0.92	0.32	2.82	.005	2.51
Experiences risk mitigation	1.50	0.44	3.40	.000	4.49
Self-efficacy knowledge	0.79	0.38	2.06	.032	2.20
Self-efficacy ability	-0.20	0.38	-0.53	.594	0.82
Past extreme events	0.13	0.20	0.62	.539	1.13
Recent extreme events	0.35	0.21	1.64	.102	1.41
Attribution	0.46	0.22	2.06	.398	1.58
Trust in climate science	0.38	0.22	1.69	.090	1.46
Dependency on forestry income	0.52	0.33	1.56	.118	1.69
Size forest property	0.00	0.00	1.83	.068	1.00
Income	0.01	0.24	0.04	.968	1.01
Education	0.11	0.22	0.51	.607	1.12
Age	-0.01	0.01	-1.34	.180	0.99
Gender	-0.08	0.26	-0.31	.760	0.92

316 of 836 observations missing
Residual deviance: 618.22 on 503 degrees of freedom
AIC: 652.22
Number of Fisher Scoring iterations: 4

These findings support hypotheses two, three and four. They also show that experience with risk mitigation is a strong factor behind individual adaptation. Results also suggest that how knowledgeable forest owners think they are about climate change helps explain their intention to change behaviour. This would imply that planned adaptation is more common than the findings in the previous section suggested, assuming knowledge about climate change that forest owners think they have is adequate.

Taken together, findings from the two regression models suggest that personal risk appraisal and belief about the connection between personal experience and climate change can universally explain individual adaption. This supports hypothesis three that if climate impacts are perceived as close and threatening, individual engagement with climate change adaptation increases (Akerlof et al. 2013). Findings also support the second hypothesis that personal belief in personal experience of climate change drives individual adaptation.

It is also important to note that affective, experiential, socio-economic factors and determinants of objective adaptive capacity do not seem to have any statistically verifiable influence on individual adaptation among forest owners. This means that results from this study do not support hypotheses one, five, six and seven. In both regression models, experiences with extreme events and levels of concern about local or global climate change are not significant. The same is true for income, education, gender, age and even level of dependency on income from forest and size of forest property. Thus, findings of this study indicate that individual adaptation cannot be adequately explained by evaluative feelings about climate change, personal experience with extreme events or vulnerability to climate impacts.

3.5 Discussion

The literature on climate change adaptation suggests that individual engagement with adaptation is determined by the reciprocal relationship between subjective and structural factors (Whitmarsh et al. 2013). Based on an integrated model of individual adaptation (Grothmann and Patt 2005; van der Linden 2015), the aim of this study was to assess and compare the influence of different structural, cognitive and experiential factors on engagement with adaptation. The study was designed to test the hypothesis that subjective factors are more powerful in explaining individual adaptation than determinants of objective adaptive capacity (Adger et al. 2009; Blennow et al. 2012).

Results from this study strongly support this hypothesis and show that cognitive factors are the only statistically significant variables that can directly explain individual adaptation to climate change by forest owners in Sweden. The data suggests that personal levels of trust in climate science and belief in experience with climate change, alongside climate risk appraisal, strongly and positively influence individuals' intention to adapt to climate change and their perceived need to adapt. As expected, findings of this study also show that among Swedish forest owners, variables related to objective adaptive capacity do not have a statistically significant influence on individual adaptation.

Unexpectedly, results did not show that affect has any direct influence on individual adaptation. Future research should investigate how affect influences individuals' perception of climate change risks (Leiserowitz 2006), perceived experience with climate change and belief in self-efficacy to better understand the effectiveness of emotive appeals to promote individual adaptation (Tannenbaum et al. 2015).

Outcomes from this study offer valuable insights for communication efforts that aim to enhance public involvement in adaptation. Results of this study confirm earlier research that has shown that personal trust in climate science is a key lever for climate awareness and action (Malka et al. 2009; Kahan et al. 2012). This highlights the importance of communication interventions to improve public trust in climate science (Goodwin and Dahlstrom 2014) to enhance awareness and knowledge about climate change impacts and adaptation options (Moser 2014).

Furthermore, findings also provide scientists and communication practitioners with a better understanding of how to promote individual adaptation by raising awareness about the proximate consequences of climate change (Brügger et al. 2015). Data clearly shows that personal belief in climate change can lead to greater sense of the need and intention to change behaviour. The study confirms earlier research that argued that experiences with extreme events alone does not automatically lead to greater climate awareness or preparedness (Whitmarsh 2008). This is consistent with previous research that has argued that links between personal experience and climate change need to be made more salient in order to increase individual's climate awareness (van der Linden 2015).

Lastly, the study also offers clues how to overcome the climate awareness action gap (Moser 2010). Results suggest that personal sense of self-efficacy related to knowledge and personal experience with risk mitigation can explain individuals' level of intent to adapt to climate

change and perceived need to adapt. These results should not be misunderstood to show that a lack of action is merely due to a lack of information. Rather, it suggests that forest owners have specific knowledge needs that need to be addressed. This supports earlier studies that have argued that communication for adaptation needs to be based on a comprehensive understanding of the needs and experiences of specific target audiences and address stakeholders' objectives and decision-making process (Pidgeon and Fischhoff 2011; Vulturius and Gerger Swartling 2015).

In conclusion, this study provides further evidence that at least in developed countries, subjective factors — namely personal levels of trust in climate science, belief in personal experience with climate change and risk assessment — are better in explaining individual engagement with adaptation than determinants of objective adaptive capacity. Furthermore, findings also strongly suggest that communication interventions that aim to promote adaptive action should focus more strongly on building trust and attending to stakeholders' individual needs and experiences.

3.7 Correction post-publication

The language of the paper has been adjusted to increase consistency with the rest of the thesis: The term attribution is used instead of the term salience that was used in the published paper. The published paper also misquoted the question about attribution beliefs. The correct question is now included.

Chapter 4: Does climate change communication matter for individual engagement with adaptation? Clues from forest owners in Sweden

4.1 Introduction

In its report on climate change and land, the Intergovernmental Panel on Climate Change (IPCC) found that global warming in high latitudes is projected to increase disturbances in boreal forests, including the risk of drought, forest fires and pest outbreaks (IPCC 2019). Similarly, climate change is expected to affect the Swedish forest sector by increasing the risk of windfall (Blennow et al. 2010b) and pests (Jönsson and Bärring 2011), as well as drought and forest fires (Lindner et al. 2014) and biodiversity loss (Felton et al. 2016). Future increases in these disturbances could cancel out the positive effects of warmer temperatures on biomass production (Reyer et al. 2017). There is an extensive literature providing advice to decision makers on how to adapt forest management to deal with the impacts of climate change (Schoene and Bernier 2012; Jönsson et al. 2013). Despite such expert warnings and advice, however, studies in the United States (Grotta et al. 2013), Canada (Bissonnette et al. 2017) and the Nordic countries (Heltorp et al. 2018), including Sweden (Lidskog and Sjödin 2014), have found that most non-industrial private sector forest owners continue to feel uncertain about the possible impacts of climate change and do not intend to take adaptive measures any time soon.

To raise awareness of climate change risk and adaptation measures, extension service providers in the forest sector are increasingly using communication interventions (Bowers et al., 2016; Krantz et al., 2013). These interventions usually involve tailor-made advice and educational support for forest owners (Mostegl et al. 2019) similar to the communication campaigns that target farmers and other professionals and communities vulnerable to climate change (Wirth et al. 2014). Examples include Forest Change, the Canadian Forest Service programme on adaptation to climate change (NRC 2019), and the Adaptation Partners programme of the US Forest Service (US Forest Service 2019). Mostegl et al. (2019) argue that communication interventions based on expert advice can be more effective at engaging with non-industrial forest owners on adaptation than payments and monetary benefits.

Despite its increase in popularity, measuring how climate change communication affects individual engagement with climate change is made difficult by the lack of conceptual clarity (Bohensky et al. 2016). This study is based on insights from risk psychology (Swim et al. 2009). It assumes that individual engagement with adaptation is driven by intrapsychic conditions, such as personal appraisal of climate change risk, perceptions of personal adaptive capacity, personal experience of extreme events and the attribution of these experiences to climate change, as well as the level of trust in climate science. Together, these factors are assumed to result in intrapsychic responses – or a personal sense of need to adapt to climate change and an intention to take adaptive action (Swim et al. 2009). Furthermore, the study understands climate change communication to be part of the societal discourse on climate change risks and adaptation (Swim et al. 2009) that influences the drivers and responses of individual engagement with adaptation (Moser 2014).

This study assesses the effects of climate change communication on individual engagement with adaptation by comparing two groups of forest owners: one that participated in the two climate communication projects organised by the Swedish Forest Agency and another consisting of a random sample of forest owners. The study asks whether there are any significant differences between the two groups in terms of intrapsychic conditions and intrapsychic responses related to adaptation. Second, it assesses whether communication has had any direct influence on forest owners' perceived need and intention to take adaptive measures. Third, the study examines the mediated or indirect influence of communication on the personal sense of the need to adapt.

To answer these questions, the study assessed the responses to a cross-sectional survey by 2402 forest owners who belonged to either of the two groups. We acknowledge that cross-sectional data is limited in its ability to measure or explain changes in personal thinking or behaviour (Ruspini 1999) and not well-suited to inferring causality between two different variables (Wittink 2004). However, we argue, based on earlier research about the validity of survey methodology (Rindfleisch et al. 2008), that cross-sectional data can nonetheless be used to infer knowledge about the dependency between two variables based on their covariance. As is explained further below, we use regression and mediation analysis to estimate the independent and mediated effects of communication on intrapsychic responses related to adaptation. This approach to analysing cross-sectional data is used in research on public health programmes (Donaldson 2001) and political communication research (Hayes et

al. 2010), including in studies about the effects of communication on public opinion on climate change (Stroud 2007).

Individual engagement with adaptation to climate change

Engagement with climate change has been defined as a personal state that simultaneously comprises cognitive, affective and behavioural aspects (Lorenzoni et al. 2007). The American Psychological Association (APA) describes adaptation as "a wide range of responses individuals can make to difficult circumstances including initial understandings, affective responses to situations, behavioural responses to situations, the process of selecting responses, and the reciprocating impacts of responses on individuals, communities, and the physical environment" (Swim et al. 2009, pp. 52–53). Thus, individual adaptation to climate change can be understood as a stepwise process that moves from understanding to planning and eventually managing adaptation (Moser and Ekstrom 2010). Given that earlier research has found that most forest owners in Sweden are neither taking nor considering action to adapt their forests to climate change (Lidskog and Sjödin 2014; Uggla and Lidskog 2016; Andersson et al. 2018), this study focuses on the effects of communication on the understanding and planning phase of individual adaptation.

In keeping with the APA's research on individual adaptation (Swim et al. 2009), assessing the effects of climate change communication on individual engagement with adaptation implies examining its influence on personal assessments of climate change-related risk (O'Connor et al. 1999), adaptive capacity (Grothmann and Patt 2005) and affective responses (van der Linden 2015), as well as individual experiences of and beliefs about extreme events (Akerlof et al. 2013). In sum, these different intrapsychic conditions are expected to result in intrapsychic responses – the sense of a need and an intention to adapt – that, depending on external circumstances, can lead to adaptive behaviour (Swim et al. 2009).

The idea that risk perception is a key driver of personal engagement with adaptation is based on earlier research on its importance to personal motivation to change behaviour (Maddux and Rogers 1983). Risk perception comprises personal appraisal of both the likelihood of being affected by climate change and the severity of the impact (Grothmann and Patt 2005). Nursey-Bray et al. (2012) showed that risk perception is an independent driver of personal intentions to adapt to climate change. It has also been suggested that people will respond to a risk if what is threatened is of value to them (Wolf and Moser 2011).

Perceived adaptive capacity refers to personal belief in the effectiveness of adaptation measures and in the personal self-efficacy of managing adaptation (Grothmann and Patt 2005). The concept of self-efficacy, on which this study focuses, was coined by Bandura (1977a). It highlights the importance of personal belief in one's own capacity for behavioural change. In their study on farmers in New Zealand, Niles et al. (2016) found that perceptions of capacity and self-efficacy were important predictors of both intended and actual adoption. How people respond to climate change also depends on their affective responses to the issue (Norgaard 2011). Feelings of concern about climate change can lead to stronger risk perception (van der Linden 2015) as well as greater perceived self-efficacy and responsibility for taking climate action (Milfont 2012).

Personal experience of extreme events can also have an influence on the level of personal engagement with adaptation (Demski et al. 2017). This assumption is based on earlier research, which has shown that personal experience of natural hazards can heighten risk appraisal and intentions to change behaviour (Weinstein 1989). Research has also suggested, however, that the effects of personal experience of extreme events on individuals may lessen over time (Kreibich et al. 2011). Furthermore, other studies have shown that experience of extreme events has no effect on personal concern about climate change (Dessai and Sims 2010) or willingness to adopt climate-friendly behaviour (Whitmarsh 2008). It has been argued that whether experience of climate-related risk leads to individual engagement with adaptation depends on whether individuals attribute such experience to climate change (Blennow et al. 2012)

Previous research on forest owners in Sweden has confirmed the relevance of at least some of the factors found to influence individual engagement with adaptation. Vulturius et al. (2018) found that personal assessment of climate change risk to their own forest was a significant factor in predicting forest owners' sense of need to take adaptation action, while Blennow et al. (2012) found that personal belief in having experienced local effects of climate change can explain adaptive behaviour among forest owners. However, previous studies have also suggested that many forest owners in Sweden are not concerned about the impacts of climate change (Eriksson 2014) or distrust climate science (Vulturius et al. 2018) and expert advice (Uggla and Lidskog 2016).

Climate change communication to promote engagement with adaptation

Climate change communication can be broadly defined as efforts to promote individual or collective awareness as well as deliberation and action on mitigation or adaptation (Johnson 2012). Over the past two decades, climate change communication has become an established field of scientific research (Nerlich et al. 2010; Moser 2014; Pearce et al. 2015) and practice (CRED 2009). A review of the literature found that studies on climate change communication broadly follow the two dominant approaches to science communication: deliberation-orientated and transmission-orientated (Ballantyne 2016). While the deliberation-orientated approach highlights the importance of participation and sense-making (Craig 1999), the transmission-orientated approach assumes that people do not act on a risk because they lack information and knowledge (Royal Society 1985).

While some have observed an increase in the use of the deliberation-orientated approach (Pearce et al. 2015), adaptation communication is still strongly influenced by the transmission-orientated approach to risk communication (Heinrichs 2010). Wirth et al. (2014) showed that most communication interventions used in 10 OECD countries were websites, printed material or mass media, while participatory formats such as workshops were in the minority. Like environmental communication (Cox 2007), adaptation communication is often understood as a crisis discipline focused on framing, targeting and tailoring science-based information (Moser, 2014; Russill and Nyssa, 2009). Thus, the transmission-orientated approach to adaptation communication is based on the idea that providing individuals with expert advice will increase their personal engagement with adaptation (Johnson 2012).

Research has shown that targeting and tailoring information about climate change can make communication interventions more relevant to their audience (Bostrom et al. 2013). Research also suggests that communication can reduce the psychological distance of climate change (Wiest et al. 2015) and lead people to attribute personal experience of extreme events to climate change (Brügger et al. 2015). Furthermore, communication is expected to influence the level of personal trust in climate science (Goodwin and Dahlstrom 2014), which has been identified as another key barrier to individual engagement with climate change (Leiserowitz et al. 2013).

Taken together, this study tests the hypothesis that transmission-orientated communication can promote individual engagement with adaptation. To test this hypothesis, the study assesses the assumptions that:

1) Forest owners who participate in climate change communication are on average more engaged with adaptation in terms of intrapsychic conditions and intrapsychic responses.
2) Climate change communication has an independent and direct effect on intrapsychic responses related to adaptation.
3) The effect of climate change communication on the personal sense of need to take climate change into greater consideration is mediated by intrapsychic conditions.

4.3 Materials and methods

This study is based on a quantitative analysis of two groups of non-industrial private sector forest owners in Sweden. The forest owners in the first group (the random group) were randomly selected from the databases of landowners in Sweden of the Swedish Mapping, Cadastral and Land Registration Authority (Lantmäteriet) and the Swedish Forest Agency. Forest owners in the second group (the communication group) were randomly selected from a list of forest owners who participated in two climate communication projects organized by the Swedish Forest Agency. In total, this study invited 6000 forest owners to participate in the study, 3000 in each group.

Climate change communication projects by the Swedish Forest Agency

Following recommendations by the Swedish Commission on Climate and Vulnerability (2007), the Swedish Forest Agency adopted a communication-based strategy to promote adaptation. As part of this strategy, the agency organised two climate communication projects: “Forest owners and climate” (Skogsägaren och klimat) and “Forestry in a changing climate” (Skogsbruk i ett förändrat klimat) (Nordström 2014). These projects took place between 2011 and 2014 and involved almost 25,000 forest owners in Sweden. The two projects took a transmission-oriented approach to communication that focused on disseminating tailored information about climate risks and adaptation measures to forest owners in evening meetings, courses or individual consultations led by experts from the Swedish Forest Agency (Nordström 2014). The Swedish Forest Agency invited forest owners from all over Sweden to participate. Those invited included a disproportionate number of

owners of larger forests, new owners and female owners. The authors of this study were not involved in the development or execution of either project.

The framing and content of the two communication projects were based on research by the Swedish Forest Agency on climate change risks and adaptation measures,[3] which was carried out in connection with the Swedish Commission on Climate and Vulnerability (2007). In both communication projects, climate change was primarily framed as a risk that needed to be addressed by individual forest owners to enable them to achieve the dual objectives of maintaining wood production and increasing environmental protection (Nordström 2014). Forest owners were told about the impacts of climate change on familiar risks such as windfall, pests or snow breakage as well as emerging risks such as increased drought and forest fires, damage caused by poorer ground conditions linked to reduced ground frost and biodiversity loss (Blennow and Eriksson 2006). In terms of adaptation, the two communication projects recommended measures to strengthen windfall resistance along forest edges, increasing the mix and diversity of tree species, harder pre-commercial thinning and cutting, shortening of the rotation period between planting and final felling, and taking out forest insurance (Eriksson 2007).

Cross-sectional survey

To assess the differences in individual engagement with adaptation between the two groups of forest owners, the study conducted a cross-sectional survey in the spring of 2014. Forest owners in both groups received a letter inviting them to take part in the study. One week later, forest owners received a copy of the survey questionnaire by post and a prepaid envelop to return the questionnaire. Owners were also given a unique personal code so that they could fill out the survey online if they did not want to mail back the questionnaire. Three weeks after the first mail-out, the owners who had not responded received a reminder by post. Another three weeks later, the forest owners who had not responded were sent both paper and electronic versions of the questionnaire. The collection of questionnaires was closed three months after owners received the invitation letter.

The response rate was 30 percent (N = 909) for the random group and 50 percent (N = 1493) for the communication group. The response size in relation to the total number of forest owners in Sweden provides a margin of error of 3.21 percent for the random group and 2.53

[3] According to conversations with Swedish Forest Agency officers in charge of the two communication projects.

percent for the communication group, at a confidence level of 95 percent. Compared to similar survey-based studies conducted with forest owners in Sweden (Nordlund and Westin 2010; Andersson 2012), the response rate for the random group was relatively low. This can be explained by the length and level of sophistication of the questionnaire.

The survey was tested in two pilot studies: First, a qualitative focus group meeting with forest owners in Southern Sweden; and second, a quantitative survey with 100 randomly selected forest owners. The survey contained questions about forest owners' socio-demographic and forest ownership attributes, personal assessment of climate change risk, level of concern, self-efficacy beliefs related to ability and knowledge, personal experience of recent and past extreme events and belief that these events have been caused by climate change. The survey also asked whether forest owners felt that they needed to take climate change communication more into consideration. Furthermore, the study asked whether forest owners had any intention to take adaptive measures in the next five years. Taken together, the questions were designed to cover intrapsychic conditions and intrapsychic responses related to the individual engagement with adaptation identified in the literature (Grothmann and Patt 2005; Swim et al. 2009).

Data analysis

In accordance with the research questions and hypothesis, the data analysis focused on assessing the differences between the two groups of forest owners and estimating the direct and mediating influences of communication on the personal sense of need to adapt and intention to adapt to climate change. The statistical software R was used for the data analysis (R Core Team 2015).

To assess the differences in the responses from random group and communication group members, the study used the Welch *t*-test and the Pearson's χ^2 test. The Welch *t*-test was used to test differences in forest owners' assessments of climate change risk, level of concern, self-efficacy beliefs, attribution beliefs, trust in climate science and sense of need to adapt, as well as in forest owners' age, size of forest property and dependency on income from forestry. The differences between the two groups are expressed in terms of significance (p value) and the effect size (r value).[4] In the context of this study, the effect size is considered

[4] An r value of 0 –.3 indicates a weak effect, .3 –.5 indicates a moderate effect and .5 – 1 indicates a strong effect (Cohen 1992). Importantly, the r value is a standardized measure that can be compared between different variables and studies (Field et al. 2012).

a measure of the influence of climate change communication on individual engagement with adaptation.

The Pearson's χ^2 test was used to assess the differences in forest owners' socio-economic and ownership attributes, experience of recent and past extreme events, and stated intention to take adaptive measures. Among the outputs of the Pearson's χ^2 test were the p value for the level of significance of the difference between the two groups and the odds ratio. The odds ratio expresses the estimated increase in the likelihood that the forest owners who participated in the Swedish Forest Agency's communication projects would intend to take adaptive measures.

Regression analysis was used to assess the direct influence of communication on the personal sense of need and intention to adapt to climate change. Multiple regression analysis was applied to explain variations in the perceived need to take climate change more into consideration. Binomial logistic regression was used to predict the variation in personal intention to take adaptive measures in the coming five years. First, a regression model was developed for both perceived need and intention to adapt using predictors suggested in the literature as relevant to individual engagement with adaptation; that is, personal assessment of climate change risk, self-efficacy beliefs, level of concern, experience of extreme events, attribution of extreme events to climate change and trust in climate science (Grothmann and Patt 2005; Swim et al. 2009). Second, hierarchical regression analysis was applied by adding communication as a predictor to each model. Third, the adjusted R^2 for the multiple regression analysis and Hosmer and Lemeshow's R^2 for the binary logistic regression analysis were calculated for both models, with and without communication as a predictor. The R^2 value expresses the amount of variation in perceived need and intention to adapt explained by each model. Fourth, changes in R^2 values were assessed using ANOVA analysis to find whether adding communication made a significant improvement to the regression model.

In addition, the study used mediation analysis developed by Baron and Kenny (1986) to assess the mediated or indirect influence of communication on the sense of need to adapt to climate change. In a similar way to how mediation analysis has been used in the evaluation of drug prevention programmes (Mackinnon and Dwyer 1993), we tested how much of communication's influence on personal sense of need to adapt came through its influence on personal assessments of climate change risk, self-efficacy beliefs, level of concern, attribution of extreme events to climate change and trust in climate science. By assessing

how its influence is mediated by these intrapsychic factors, the analysis provides insights into *how* communication influences the personal sense of the need to adapt (cp. MacKinnon et al., 2007). Methodological issues with dichotomous variables in mediation analysis (Mackinnon and Dwyer 1993) meant that experience of extreme events and intention to adapt were not considered in the analysis. The mediation analysis was conducted using the "mediation" package in R (Tingley et al. 2014).

4.4 Results

Differences in socio-demographic and forest ownership attributes

Table 4.1 compares the socio-demographic and forest ownership attributes of forest owners in the random group with those in the communication group. According to Swedish Forest Agency's statistics, male forest owners and forest owners with forest property exceeding 100 ha were overrepresented in both groups (Swedish Forest Agency 2014). The results of the statistical analysis show that, on average, forest owners in the communication group were more often dependent on income from forestry and tended to have a higher income and level of education than those in the random group. They were also more likely to be members of forest owners' associations and to adhere to forestry certification programmes such as those of the Forest Stewardship Council (FSC) or the Programme for the Endorsement of Forest Certification (PEFC).

The comparison also found that more forest owners in the communication group had experienced extreme events in the past 10 years, which includes the period in which the two climate communication projects took place. Notably, around one-third of forest owners reported having been affected by Storm Gudrun in 2005.

Taken together, the results suggest that the Swedish Forest Agency climate communication projects attracted forest owners who were more involved in the management of their forest, as measured by their economic dependency, certification and membership of ownership associations, compared to their peers in the general private sector forest owner population in Sweden (Swedish Forest Agency 2014). The data also indicates that having experienced extreme events was an important motivator of participation in the communication projects.

Differences in forest owners' intrapsychic conditions and intrapsychic responses

Table 4.2 shows the results of the examination of forest owners' intrapsychic conditions and their intrapsychic responses related to individual engagement with adaptation and the

statistical analysis of the differences between the two groups. Regardless of to which group they belonged, forest owners appeared to be relatively undecided about adaptation. The average response was around three on a scale from one to five with a standard deviation of around one.

Table 4.1: Differences in socio-demographic and forest ownership attributes, experience of extreme events between the two groups of forest owners

Group differences	Randomly Group	Communication group	Test of difference[d]	
Attribute	**Mean (standard deviation)**		**p value**	**r value**
Age	65 (12)	66 (11)	<.001	.09
Monthly household income[a]	6.32 (2.90)	6.59 (2.83)	.031	.05
Size of forest property[b]	3.27 (1.49)	3.96 (1.51)	<.001	.27
Dependency on income from forestry[c]	2.05 (1.14)	2.45 (2.21)	<.001	.17
	Share of respondents		**p value**	**Odds ratio**
Female	22.6%	19.16%	.042	0.81
Member of a forest owners' association	45.54%	59.93%	<.001	1.58
Certified forest	22.11%	40.05%	<.001	2.35
Have experienced extreme events in the last 10 years (Past extreme events)	47.41%	58.40%	<.001	1.56
Have experienced extreme events in 2013-2014 (Recent extreme events)	28,16%	26,34%	<.001	1.46

[a]Income level: 1 = 5000 SEK; 2 = 5001–10.000 SEK; 3 = 10.001–15.000 SEK; 4 = 15.001–20.000 SEK; 5 = 20.001–25.000 SEK; 6 = 25.001–30.000 SEK; 7 = 30.001–35.000 SEK; 8 = 35.001–40.000 SEK; 9 = 40.0001–45.000 SEK; 10 = 45.001–50.000 SEK; 11 = 50.001–55.000 SEK; 12 = 55.001 SEK or more. In April 2014, 1 SEK = ca. US$ 0.151.
[b]Size of forest property: 1 = 1–5 ha; 2 = 6–20 ha; 3 = 21–50 ha; 4 = 51–100 ha; 5 = 101–200 ha; 6 = 201–400 ha; 7 = 401–1000 ha; 8 =1001 ha or more.
[c]Dependence measured on a 5-point Likert scale ranging from 1 = Not dependent to 5 = Very dependent.
[d]Statistical tests: Welch's *t*-test = Age, Monthly household income, Size of forest property, Dependency on income from forestry; Pearson's chi-squared test = Female, Certified forest, Member of forest owners' association, Have experienced extreme events in the past 10 years, Have experienced extreme events in 2013–2014

The statistical analysis also shows that compared to their peers in the random group, the forest owners who took part in the climate change communication were more concerned about the risk of climate change to their forest and considered this risk to be more serious. Forest owners in the communication group also believed more strongly in their own ability to adapt to climate change, in the trustworthiness of climate science and that extreme events in the past were caused by climate change.

The comparison also reveals that, on average, communication group members had a greater perceived need to take climate change into consideration than the random group. The analysis of the r values, however, also suggests that communication has a weak effect on forest owners' general views on adaptation and their perceived need for greater consideration of the topic. Nonetheless, the analysis shows that forest owners who have

participated in communication were 2.3 times more likely to intend to take adaptive measures in the near future.

Table 4.2: Differences in intrapsychic conditions and intrapsychic responses between the two groups of forest owners

Group differences	**Random group**	**Communication group**	**Test of difference[b]**	
Statement[a]	**Mean (standard deviation)**		**p value**	**r value**
I consider the risk of climate change to my own forest to be very serious (Risk assessment)	2.90 (1.10)	3.00 (1.10)	.027	.05
I believe that I am capable of adapting my forest to climate change (Self-efficacy ability)	2.67 (1.07)	2.97 (1.11)	<.001	.16
I believe that I have enough knowledge to adapt my forest to climate change (Self-efficacy knowledge)	2.69 (1.10)	3.03 (1.10)	<.001	.19
I am very concerned about the risk of climate change to my own forest (Concern)	2.87 (1.08)	3.03 (1.11)	.002	.07
I believe that extreme events in Sweden in the past 10 years have been caused by climate change (Attribution)	3.13 (1.21)	3.23 (1.20)	.046	.05
I consider climate science to be trustworthy (Trust)	3.22 (1.11)	3.32 (1.10)	.005	.07
I need to take climate change into greater consideration (Perceived need to adapt)	2.75 (1.10)	3.00 (1.05)	<.001	.15
Question	**Share responding "Yes"**		**p value**	**odds ratio**
Are you planning to take risk-mitigating measures to address climate change in the coming five years?" (Intention to adapt)	37%	58%	<.001	2.30

[a] Responses to the statement were given on a Likert scale from 1 = "strongly disagree" to 5 = "strongly agree".
[b]Statistical tests: Welch's *t*-test = Age, Monthly household income, Size of forest property, Dependency on income from forestry; Pearson's chi-squared test = Female, Certified forest, Member of forest owners' association, Have experienced extreme events in the past 10 years, Have experienced extreme events in 2013–2014

Influence of climate change communication on intrapsychic responses related to adaptation

Aside from assessing the difference between the two groups of forest owners, the study also asked about the direct influence of communication on perceived need and intention to adapt compared with intrapsychic conditions. Table 4.3 shows the results of two multiple regression models. Model 1 only includes intrapsychic conditions as predictors, whereas Model 2 also includes forest owners' participation in the Swedish Forest Agency's communication projects. When considering the p value and the standardized β coefficient, results for Model 1 show that the most important predictor of perceived need to adapt is risk assessment followed by concern about the risk of climate change to one's own forest, trust in climate science, attribution of extreme events to climate change, belief in having the ability to adapt personal forest property to climate change and personal experience with extreme events in past 10 years. The adjusted R^2 shows that these predictors combined explain 35

percent of the variation in perceived need to adapt. Adding communication to the model resulted in a statistically significant improvement of the model by explaining, *ceteris paribus*, two percent more of the variation. The results also suggest that communication had a similar influence on forest owners' perceived need to address climate change to trust, attribution or concern.

Finally, Table 4.4 shows the results of two binary logistic regressions models. These models have the same set of predictors as the multiple regression models. The p values and odds ratio identify experience of recent and past extreme events and personal belief in personal knowledge to adapt one's own forest were the three most important predictors of personal intention to take adaptive action, followed by risk assessment, attribution and trust. However, Hosmer and Lemeshow's R^2 shows that the model is relatively poor at explaining personal intention to take adaptive measures.

Table 4.3: Hierarchical multiple regression of forest owners' perceived need to adapt

	Adjusted R^2	**Estimate**	**Standard error**	**β**	**p-value**
Model 1	0.35				
Intercept		0.49	0.11		<.001
Risk assessment		0.32	0.03	0.32	<.001
Self-efficacy ability		0.09	0.03	0.09	.005
Self-efficacy knowledge		-0.01	0.03	-0.01	.718
Concern		0.14	0.03	0.14	<.001
Recent extreme events		-0.03	0.04	-0.01	.519
Past extreme events		0.09	0.04	0.04	.032
Attribution		0.11	0.02	0.12	<.001
Trust		0.14	0.02	0.14	<.001
Model 2	0.37				
Intercept		0.23	0.12		.055
Risk assessment		0.32	0.03	0.32	<.001
Self-efficacy based on ability		0.09	0.03	0.09	.003
Self-efficacy based on knowledge		-0.03	0.03	-0.03	.375
Concern		0.14	0.03	0.14	<.001
Recent extreme events		-0.03	0.04	-0.01	.426
Past extreme events		0.07	0.04	0.03	<.066
Attribution		0.10	0.02	0.12	<.001
Trust		0.13	0.02	0.13	<.001
Communication		0.27	0.04	0.13	<.001

542 out of 2402 observations missing.
Anova analysis shows that Adjusted R^2 of Model 1 and Model 2 differ significantly (<.001)
Model 1: Residual standard error: 0.8453 on 1851 degrees of freedom. F-statistic: 126.7 on 8 and 1851 DF, p value: <.001
Model 2: Residual standard error: 0.8359 on 1850 degrees of freedom. F-statistic: 120 on 9 and 1850 DF, p value: < .001

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Table 4.4: Hierarchical binary logistic regression of forest owners' intention to adapt

	Hosmer and Lemeshow's R^2	Estimate	Standard error	Z-value	p-value	Odds ratio
Model 1	0.11					
Intercept		-4.63	0.33	-14.19	<.001	0.01
Risk assessment		0.23	0.09	2.57	.010	1.26
Self-efficacy ability		0.05	0.08	0.59	.555	1.05
Self-efficacy knowledge		0.29	0.08	3.54	<.001	1.33
Concern		0.13	0.08	1.49	.136	1.13
Recent extreme events		0.43	0.11	3.95	<.001	1.54
Past extreme events		0.65	0.10	6.28	<.001	1.91
Attribution		0.19	0.05	3.60	<.001	1.20
Trust		0.18	0.05	3.45	<.001	1.20
Model 2	0.13					
Intercept		-5.34	0.35	-15.07	<.001	0.00
Risk assessment		0.23	0.09	2.61	.009	1.26
Self-efficacy ability		0.05	0.08	0.60	.550	1.05
Self-efficacy knowledge		0.26	0.08	3.12	.002	1.30
Concern		0.12	0.09	1.40	.160	1.13
Recent extreme events		0.422	0.11	3.84	.001	1.53
Past extreme events		0.63	0.10	6.06	<.001	1.88
Attribution		0.19	0.05	3.54	<.001	1.20
Trust		0.16	0.05	3.07	.002	1.18
Communication		0.66	0.11	6.07	<.001	1.93

546 out of 2402 observations missing.
Anova analysis shows that Hosmer and Lemeshow's R^2 of Model 1 and Model 2 differ significantly (p value <.001)
Model 1: Residual deviance: 2268.9 on 1847 degrees of freedom. AIC: 2286.9. Number of Fisher Scoring iterations: 4
Model 2: Residual deviance: 2231.4 on 1846 degrees of freedom. AIC: 2251.4. Number of Fisher Scoring iterations: 4

Like the multiple regression models, adding communication to the list of predictors slightly improved the explanatory power of the binary logistic regression model, as indicated by the change in Hosmer and Lemeshow's R^2 from .11 to .13. A comparison of the odds ratio, however, suggests that communication is the strongest predictor of personal intention to adapt to climate change.

Mediated influence of climate change communication on perceived need to adapt

Finally, the study asked whether the influence of communication on personal sense of need to adapt is mediated through communication's influence on other intrapsychic conditions. Figure 4.1 depicts how mediation analysis according to Baron and Kenny (1986) has been applied in this study. In a first step, a linear regression analysis was used to confirm that communication had a statistically significant effect on forest owners' sense of need to adapt (Adjusted R^2 0.03, p value <.001). We then followed the approach proposed by Shrout and Bolger (2002) by conducting a single-mediator analysis based on two separate regression models: a regression model to assess the effect of communication on a given intrapsychic driver and a regression model to predict the shared effect of communication and a given intrapsychic condition on sense of need to adapt.

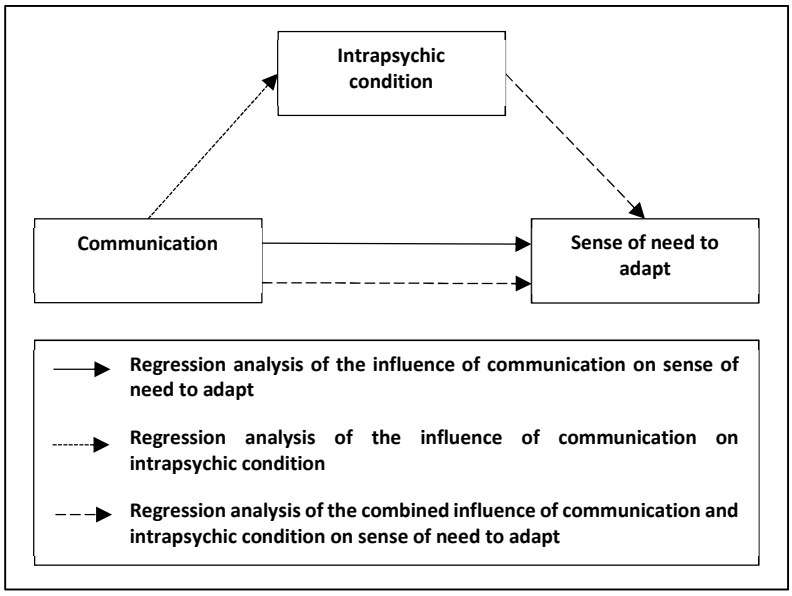

Figure 4.1: Single-mediator analysis of perceived need to adapt

Table 4.5 shows the relation between the mediation analysis of communication and the perceived need to adapt with a single mediator. The Average Causal Mediation Effect (ACME) can be interpreted as the indirect effect of communication on perceived need to adapt through its influence on a single intrapsychic condition. Like the r value in Table 4.2, the ACME suggests how well communication affected a given intrapsychic condition that drives personal need to adapt. The Average Direct Effect (ADE) is the direct effect of communication on perceived need to adapt without considering its indirect effect through a given

intrapsychic condition. The proportional mediated effect shows how much of the total effect of communication was indirect, linked to a given intrapsychic condition.

The results show that when only considering communication and risk assessment, 16 percent of the communications effect on perceived need to adapt was linked to its effect on risk assessment. In the case of concern, this was 18 percent, while for attribution the figure was 14 percent and 19 percent of communication's influence was linked to trust. The analysis also suggests that communication had no significant indirect influence through enhanced self-efficacy belief. Overall, the results of the mediation analysis support the findings of the Welch's *t*-test and regression analysis that communication had little direct or indirect influence on personal perceived need to take climate change into greater consideration.

Table 4.5: Mediation analysis of direct and indirect effect of communication on perceived need to adapt

	ACME[a]		**ADE[b]**		**Proportional mediated effect**	
Mediators	**Estimate**	**p value**	**Estimate**	**p value**	**Estimate**	**p value**
Risk assessment	0.06	.012	0.33	<.001	0.16	.012
Self-efficacy ability	0.01	.100	0.39	<.001	0.02	.100
Self-efficacy knowledge	0.01	.360	0.39	<.001	0.02	.360
Concern	0.07	>.001	0.32	<.001	0.18	>.001
Attribution	0.05	>.001	0.32	<.001	0.14	>.001
Trust	0.08	>.001	0.32	<.001	0.19	>.001

[a] Average Causal Mediation Effect of Communication and a single intrapsychic condition
[b] Average Direct Effect of communication only
p values based on bootstrapped regression with 500 simulations based on Tingley et al. (2014)

4.5 Discussion

Individual adaptation to climate change is a complex psychological process (Bradley and Reser 2017) that, depending on external barriers, can lead to individual or collective action (Grothmann and Patt 2005; Swim et al. 2009). This study had as its objective assessing the effects of climate change communication on intrapsychic conditions and intrapsychic responses related to individual engagement with adaptation. To achieve its objective, the study analysed survey responses from two different sets of forest owners: a group of those who had taken part in climate change communication projects organised by the Swedish Forest Agency and a group consisting of a random sample of members.

Communication has little measurable direct effect on intrapsychic antecedents of individual engagement with adaptation

Overall, the statistical analysis suggests that communication can have a significant but only small direct effect on individual engagement with adaptation. The differences between the two groups showed that, on average, forest owners who had participated in communication organised by the Swedish Forest Agency perceived the risk of climate change to their forest to be more severe than their peers, had a stronger belief in their self-efficacy, were more concerned, were more likely to attribute their experience of extreme events to climate change and had greater trust in climate science. As might be expected, climate change communication appeared to have the strongest influence on forest owners' conviction that they had enough knowledge to adapt to climate change. However, the results of the statistical tests showed that, overall, the effect of communication on intrapsychic conditions and intrapsychic responses was weak. Furthermore, the results also show that forest owners in both groups were mostly undecided on the issue of adaptation. Nonetheless, the forest owners who had received expert advice from the Swedish Forest Agency where more likely to intend to take adaptive measures in the next five years. The multiple regression analyses confirmed the weak direct effect of communication on personal perceived need to adapt and the relatively stronger influence on personal intention. Taken together, these results seem to confirm earlier research, which has shown that forest owners in Sweden (Uggla and Lidskog 2016) and land managers elsewhere (Carr and Onzere 2018) are not easily swayed by expert advice on climate change.

One possible reason for the small direct effect of communication on intrapsychic conditions and responses related to personal engagement with adaptation could be the transmission-orientated approach to communication taken by the Swedish Forest Agency. Research suggests that adopting a deliberation-orientated approach to communication (Johnson 2012) can be more effective at increasing concern, deepening understanding and changing beliefs and attitudes about climate change (Moser 2016). Experience with Useful to Usable (U2U) program at the US Department of Agriculture identifies knowledge co-creation and participatory decision-making as effective strategies for facilitating greater engagement with climate science and action (Prokopy et al. 2017).

Indirect effects of climate change communication are even smaller, but offer new insights for communication design

This study also asked about the indirect effects of communication. To answer this question, we used mediation analysis (Baron and Kenny 1986), which is commonly used in research about public health (Donaldson 2001) and political communication (Hayes et al. 2010). The results suggest that 14–19 percent of the effect of communication on the perceived need to take climate change into greater consideration was mediated by its effect on forest risk perception, concern, attribution beliefs and trust in climate science. Notably, the analysis did not show that communication affected perceived need to adapt by improving forest owners' belief in personal ability or possession of knowledge to adapt their forest. This suggests that even though communication improved people's belief that they were knowledgeable about the issue, this effect was not strong enough to indirectly influence people's perceived need to act on climate change.

The study also showcases how mediation analysis can be used to assess *how* climate change communication influences people's behavioural intentions and actions. As Hayes (2009) argues, mediation analysis can be used to test assumptions about the causal links through which communication exerts influence on human cognition, emotion and behaviour. The findings of this study appear to support the assumption that communication can affect individual responses to climate change by enhancing trust in climate science (Goodwin and Dahlstrom 2014), increasing concern (Roeser 2012) and increasing people's assessment that they are at risk from climate change and their belief that they have experienced its impacts (Marx et al. 2007). Mediation analysis can also be used to assess how communication can promote individual engagement with adaptation by improving people's belief in the effectiveness of specific adaptation measures (cp. van Valkengoed and Steg 2019)

Possibilities and shortcomings of using quantitative, cross-sectional survey data to assess the effect of communication on individual engagement with adaptation

The study follows the argument made by Rindfleisch et al. (2008) that cross-sectional survey data can be used to infer knowledge about the connection between communication and individual engagement with adaptation. Data from cross-sectional surveys has been used to estimate the effects of marketing (Gordon et al. 2011) and public health (Adebajo et al. 2015) campaigns on personal attitudes and behaviour. Cross-sectional data is also used by

practitioners, including the Swedish Forest Agency (Arvidsson 2014), to evaluate the outcomes of climate change communication.

However, we also acknowledge that cross-sectional survey data has two key shortcomings that need to be considered when interpreting the results of this study. First, cross-sectional data cannot be used to make definitive statements about temporal order of cause and effect (cp. Davis 1985), such as, for example, that after participating in the Swedish Forest Agency's communication projects forest owners were more likely to intend to take adaptive action. Second, quantitative data from surveys is insufficient for identifying how people make sense of new information and experiences (Bryman 2012). To address both weaknesses, research has used panel data (Howell 2014) and qualitative data (Vulturius et al. 2019) to improve understanding of the effects of communication on individual engagement with climate change.

Experience of extreme events and attribution drive individual engagement with adaptation

In addition to the direct and indirect effects of climate change communication, the study provides insights into the effect of having personal experience of extreme events. There is disagreement in the literature about the effect that personal experience of extreme events has on individual engagement with climate change (Dessai and Sims 2010; van der Linden 2015) and the importance of individual belief in a causal relationship between such experiences and climate change in decisions to consider taking adaptive action (Morris et al. 2016).

The results of this study largely support the earlier findings of Blennow et al. (2012), which show that personal experience of extreme events and belief that these events were caused by climate change motivate people to engage in adaptation. Our study adds that the influence of attribution and experience varies depending on the intrapsychic response. The findings suggest that personal experience appears to have only a small influence on personal sense of need to adapt, while attribution has a larger influence. However, the effect of personal experience was larger on personal intentions to adapt than people's belief that their experience could be attributed to climate change. Thus, unlike earlier research which suggested that experience of extreme events is associated with increased engagement with climate change only when these events are attributed to climate change (Reser et al. 2012),

our results suggests that experience of extreme events affects peoples intentions to take adaptive measures regardless of their attribution beliefs.[5]

Looking beyond generic intrapsychic conditions to understand individual engagement with adaptation

Notably, the results of the multiple regression analysis presented in this study suggest that intrapsychic conditions and communication combined explain only one-third of the observed variation in forest owners' perceived need to adapt and are even less powerful in explaining personal intentions to take adaptive measures in the near future. These findings compare well with a recent meta-review of psychological factors behind individual adaptation (van Valkengoed and Steg 2019), which found that intrapsychic conditions, including those considered in this study, on average have a weak to moderate effect in terms of their r value on personal intended and actual adaptive behaviour.

How people appraise and feel about risks and adaptation options also depends on their values (O'Brien and Wolf 2010). Considering how personal values shape risk perceptions and beliefs in adaptation outcomes is part of actor-based adaptation research (Eisenack et al. 2014). Previous research suggests that forest owners' in Sweden (Kindstrand et al. 2008) and elsewhere (Wiersum et al. 2005) have diverse personal forest-related values, for example on income generation or environmental protection, that influence their assessment of risk (Eriksson 2014), attitude to forest management measures (Nordlund and Westin 2010) and capacity to adapt to climate change (Blanco et al. 2015).

Furthermore, the literature also highlights that individuals do not adapt in a social vacuum (Grothmann and Patt 2005). Similarly, the potential for communication to alter individual engagement with adaptation is constrained by meso- and macro-level barriers (Flagg and Kirchhoff 2018). As Adger et al. (2009) argue, norms and rationales can place social limits on individual and collective adaptation to climate change. Even though forest owners in Sweden post-deregulation are relatively free to manage their own forests (Appelstrand 2012), research suggests that many of them, voluntarily or involuntarily, maintain the forest industry's focus on wood production and short-term economic gain, which makes them less

[5] The study did not assess whether personal experience of extreme events led to attribution beliefs or pre-existing attribution beliefs led people to believe that new experiences were a result of climate change (cp. Reser et al. 2014). Research by Myers et al. (2013) has found evidence that experiential learning (seeing is believing) is stronger among people who are less engaged with climate change and motivated reasoning (believing is seeing) is stronger in individuals who are highly engaged with the topic.

concerned about the long-term consequences of climate change (Lidskog and Sjödin 2014; Lidskog and Löfmarck 2015). Keskitalo (2009) found that globalisation and international competition are key barriers to adapting industrial forest management to climate change. However, there is also evidence that forest owners are starting to challenge the industry's business-as-usual approach to climate change risk and adaptation (Andersson and Keskitalo 2018; Andersson et al. 2018).

Conclusions

In conclusion, the findings of this study show that expert-driven climate change communication had little effect on individual engagement with adaptation by forest owners in Sweden. The study also suggests that mediation analysis can be used to better understand the indirect effects of communication and to design future communication interventions. Future research should make use of longitudinal and qualitative data to build a better understanding of the long- and short-term effects of communication and how people learn and make sense of expert advice and co-developed knowledge. This research should also investigate whether a stronger focus on solutions might improve people's behavioural intentions and actions to adapt to climate change.

Chapter 5: Successes and shortcomings of climate communication: insights from a longitudinal analysis of Swedish forest owners

5.1 Introduction

In its most recent assessment report (AR5), the Intergovernmental Panel on Climate Change (IPCC) highlighted the importance of communication for raising awareness about climate change risks, disseminating knowledge about adaptive measures, and building adaptive capacity for individual and collective action (Noble et al. 2014). Communication of climate science to promote individual adaptation is increasingly being used in environmental planning and management in developed (Bowers, Monroe, and Adams 2016) and developing countries (Tomlinson and Rhiney 2018).

Communicating relevant information in a way that audiences find engaging is key for the success of any kind of environmental communication (Monroe et al. 2017). Participatory, science-based forms of communication, such as science–stakeholder dialogues (Welp et al. 2006), are designed with this in mind. Science–based stakeholder dialogues have been shown to raise awareness and improve understanding about climate change (Jönsson and Gerger Swartling 2014) and to help individuals overcome barriers to adaptation (Vulturius and Gerger Swartling 2015).

While there is general agreement that the objective of climate communication for adaptation is to promote personal engagement in terms of awareness, motivation, capacity and action (Moser 2014), measuring and evaluating how climate communication affects individuals remains difficult (Bohensky et al. 2016). Research has shown that individual perception, understanding, planning and action on climate change is subject to complex cognitive, behavioural and external factors that shape peoples' attitudes about climate risks, adaptation options, personal capacity to adapt to climate change and the usefulness and trustworthiness of climate science (Grothmann and Patt 2005; Kahan et al. 2011).

This study aims to develop an empirically based understanding of the influence of participatory climate communication on individual engagement with adaptation. It asks the question if climate communication can lead to intrapsychic and behavioural change among forest owners in Sweden. To answer this question the study uses an analytical model that

proposes that individual engagement with adaptation is determined by cognitive, behavioural and external factors (Grothmann and Patt 2005).

The study draws from qualitative and quantitative data and uses a longitudinal panel design that has been adopted from previous research on the short- and long-term effects of climate communication on individual engagement with climate change (Howell 2014). This mixed-method design forms the basis of a comprehensive assessment of the outcomes of climate communication in terms of individual intrapsychic and behavioural change (Gerlak et al. 2018).

Individual adaptation to climate change

Individual adaptation to climate change refers to short- and long-term changes in attitudes and behaviour that people engage in to mitigate or respond to experienced or anticipated climate-related impacts (Smit and Wandel 2006a; Adger et al. 2009). While some studies have shown that forest owners in Sweden are increasingly becoming more aware about climate risks and are starting to consider taking adaptative action (Keskitalo 2011), other research has suggested that they are also struggling to change their forest management practices (Andersson and Keskitalo 2018) and are unlikely to take adaptation measures soon (Vulturius et al. 2018).

Climate change is expected to affect Swedish forest owners in multiple ways: greater temperature increases than the global average and altered precipitation patterns (SMHI 2014), increased risks from pests and pathogens (Jönsson and Bärring 2011), longer extreme drought conditions and shorter periods of frozen ground (Lindner et al. 2014); but also improved growing conditions (Swedish Commission on Climate and Vulnerability 2007).

To better understand the influence of climate communication on individual adaptation, it is necessary to identify the key factors that help explain why it is difficult for individuals to move from understanding climate change risks to planning and eventually implementing adaptation measures (Moser and Ekstrom 2010).

This study is based on an analytical model of individual adaptation to climate change put forward by (Grothmann and Patt 2005). The model draws from the social cognitive theory (Bandura 1989) which argues that human motivation and behaviour is the result of the reciprocal relationship between cognitive, behavioural and external factors. Grothmann and

Patt's model has been used in two earlier studies on individual adaptation to climate change by Swedish forest owners (André et al. 2017; Vulturius et al. 2018).

Based on the protection motivation theory (Maddux and Rogers 1983), Grothmann and Patt (2005) argue that individual engagement with adaptation depends on how individuals perceive climate risks and how they appraise adaptation options. Personal perception of climate change risks refers to the perceived severity and likelihood of being affected by climate impacts (Grothmann and Patt 2005). Previous research has shown that individuals' risk perception can differ considerably from expert risk assessment (Slovic 2000). For example, risks from climate change may be perceived as higher if they threaten something that is of great importance to an individual, implying that people's values and norms greatly influence how they perceive risks from climate change (Wolf et al. 2013).

How individuals perceive the risks of climate change also greatly depends on their emotional response to the issue. Concern about climate change has been found to be one of the strongest predictors of personal climate risk perception (van der Linden 2015) and personal behavioural intention for adaptation (Vulturius et al. 2018).

Perceived adaptative capacity refers to peoples' belief in their own ability to adapt to climate change and to cope with its impacts (Grothmann and Patt 2005). Individuals assess their own ability to engage in adaptive behaviour in response to new threatening information or events (Gifford et al. 2011). The idea that stronger belief in personal ability to adapt to climate change is a driver for is related to the concept of self-efficacy included in the social cognitive theory (Bandura 2001). Strong belief in self-efficacy has been shown to have a positive influence on both intended and actual adaptation (Niles et al. 2016).

As for behavioural factors, experience of climate-related extreme events is one of the key drivers behind individual engagement with adaptation (Demski et al. 2017). Research has shown that experience with extreme events creates opportunities for people to become convinced of the reality of climate change (Myers et al. 2013). To what extent personal experiences can contribute to long-term and proactive climate adaptation depends on whether individuals connect their personal experiences to climate change (Akerlof et al. 2013).

Climate change communication for adaptation

In Grothmann and Patt's model, climate communication can be understood as one of the many external factors that influence how engaged individuals are with adaptation. Previous research has presented evidence that climate communication can influence personal awareness about climate risks and motivation to take adaptive measures (Vulturius and Gerger Swartling 2015). However, the literature also stresses that simply providing individuals with more knowledge does not automatically lead to greater engagement with climate change (Moser 2014).

Using information and knowledge that is tailored to the decision making conditions and needs of its audience has been found to be one success factor of climate communication (Bostrom et al. 2013). Another is using communication methods that participants find engaging and that give them the opportunity to discuss personal experiences and scientific knowledge with their peers and experts (Vulturius and Gerger Swartling 2015).

Like other forms of environmental communication, the effect climate communication has on individuals also relies on its perceived credibility. Trust in science and science-based communication depends on how individuals perceive of scientists´ knowledge, expertise, honesty and transparency (Peters et al. 1997). Research suggests that climate scientist can build greater trusts in their work by engaging with doubtful and dismissive audiences, undertaking burdens of proof to argue with them, empowering audiences to assess the science themselves, admitting error, and focusing on small issues (Goodwin and Dahlstrom 2014).

It has also been suggested that communication for adaptation should focus on helping people connect their experience of climate-related extreme events to climate change (Brügger et al. 2015) since personal belief to have experienced climate change has a strong bearing on risk perception and adaptive behaviour (Blennow et al. 2012).

Taken together, this study will test the hypothesis that participatory climate communication can influence forest owners' intrapsychic and behavioural engagement with adaptation. To test this hypothesis, we will examine the following assumptions. After taking part in climate communication, forest owners will:

1) Have changed their perception of and become more concerned about the risk of climate change globally and for their own forest.
2) Believe more strongly that they have enough knowledge to adapt their forest to climate change.
3) Trust climate science more.
4) Have become more convinced that they have experienced climate change.
5) Consider the need to take climate change into greater consideration to be more urgent.
6) Have changed how they manage their forest and take more risk mitigating measurers.

5.2 Materials and Methods

To test the hypothesis that climate communication can influence individual engagement with adaptation, we engaged 45 forest owners in Sweden in a participatory climate communication process. Intrapsychic and behavioural changes in forest owners were measured using qualitative interviews that were conducted six months after the end of the communication process. Additionally, forest owners also responded to questionnaires before the communication process had started, immediately after it had ended and four-and-a-half years after the starts of the communication process.

It should be note that due to the small number of forest owners that were involved in this study and how they were sampled (see next section), results cannot be generalized to all Swedish forest owners.

A participatory climate communication process with forest owners in Sweden

The communication process was designed as a participatory science-based stakeholder dialogue (Welp et al. 2006a) that encompassed a series of three focus group meetings and one workshop. Following the approach developed by Welp et al. (2006b) the focus groups meetings and workshop were set-up to enable the sharing of knowledge and perspectives, reflection and learning among scientists and forest owners, and to gain greater insights into the complexity and realities of individual forest management (see (André et al. 2016) for further details). Thus, in comparison with other types of focus groups the meetings were more structured – for example through the use of different participatory techniques such as brainstorming and ranking exercise – and involved scientific input to inform the discussions and facilitate knowledge exchange between the participants (Kasemir et al. 2003).

In total, there were seven focus groups, two in each region except for one, which met on three separate occasions over a four-month period, starting in late November 2013 and ending in the beginning of March 2014. Each meeting lasted about two and a half hours and was led by two facilitators. All meetings were recorded and transcribed verbatim. The communication process was finalized with a workshop that was held in Stockholm in November 2014 involving 26 participants from all groups.

Forest owners who participated in the communication process were selected to represent different geographic areas, socio-demographic backgrounds and experiences as forest managers. To identify and select this diverse set of forest owners for the focus groups, contacts were made with local and regional organizations such as the Swedish Forest Agency, forest owner associations, consultants and wood buyers/sawmill companies.

In sum, forest owners came from four different regions in the north, centre and south of Sweden that have different climatic and forest conditions; 30% of them were female; they were between 30 and 81 years old; and individually they owned between 20ha and more than 1000ha of forest. Almost all forest owners had their forestry certified according to the Forest Stewardship Council (FSC) or the Programme for the Endorsement of Forest Certification (PEFC) standard, and 36% said that they were dependent on income from forestry. In addition, almost a third of forest owners had observed changes to local weather and climate conditions over the last 30 years.

The *first* focus group meeting aimed to set the issue of climate change and adaptation in context and create a baseline for further discussions. Forest owners were asked to discuss their perceptions of current and future challenges and risks as well as their current understanding of climate change.

The *second* focus group meeting aimed to go deeper into what climate change means in the four different regions and the implications for the forestry sector both in terms of climate impacts, and adaptation options and needs. This meeting also included two scientific presentations made by a climate scientist from the Swedish Meteorological and Hydrological Institute (SMHI) and forest researchers from Lund University. The presentations were interactive and included: future climate scenarios for each of the four regions and an overview of how climate scenarios are developed, climate change impacts on forestry (e.g. shifting of vegetation zones, changes in growth periods, risks from storms) and forest management options (Jönsson et al. 2013), as well as a model of reactive measures to storms

(salvage cutting and reforestation), as well as active measures (e.g. shorter rotation period between planting and final felling) and non-conventional measures (e.g. continuous cover forest management) to address the impact of climate change (Table 5.3). Forest owners and the scientist then identified and discussed the different forest management options and their practical implications.

During the *third* and final meeting, forest owners discussed synergies and conflicts between different forest management options and how these link to climate adaptation. The meeting also focused on the role and responsibilities of different actors in relation to climate adaptation, how to improve trust in climate science and how to communicate scientific information and to whom. Some forest owners also took part in a *workshop* eight months after the third focus group meeting that gave them the opportunity to reflect on the focus group meetings, and exchange experiences and insights.

Qualitative data collection and analysis

To assess the effect of the communication process on forest owners' level of engagement with adaptation, we conducted interviews with 40 of the forest owners six month after the last focus group meeting[6]. Each interview lasted about 20-30 minutes and followed a semi-structured approach to capture forest owners' reflections about the focus group meetings, their views on climate risks, adaptation options, climate science, and self-reported learning. The interviews were conducted by an interviewer who was not involved in the focus group meetings to give forest owners the opportunity to express their reflections freely and to provide honest feedback.

The interviews were conducted via telephone and the records were transcribed verbatim. Deductive coding was used in the analysis of the interview transcripts. Coding focused on the cognitive and experiential factors behind individual engagement with adaptation that were described in section 5.1: perception of, and concern about climate change risks, belief in personal experience of climate change, trust in climate science, belief in personal knowledge to adapt to climate change, perceived need to take climate risk into greater consideration, experience of climate-related extreme events and changes in forest management. Where quotations are presented in the results section, they are taken verbatim from the interview transcripts, translated from Swedish and edited for readability.

[6] The remaining 5 did not wish to take part, or were unreachable

Quantitative data collection and analysis

In addition to qualitative interviews, the study also used a set of three questionnaires that forest owners were asked to fill in immediately before the first focus group meeting in November 2013 (T-0), immediately after the third and last focus group meeting in March 2014 (T-1), and four-and-a-half years after the first focus group meeting in spring 2018 (T-2). The first questionnaire was completed by 43 of the 45 forest owners who took part in the focus group meetings, and the second and third questionnaires were completed by 39 and 41 forest owners, respectively. Not all forest owners responded to each question and to each questionnaire. This is the reason why the number of cases for the statistical analysis varies between 35 and 37.

While the first two questionnaires were handed out in person, the third questionnaire was sent by email, and by regular mail if requested or if forest owners had not given a valid email address before. Two reminders were sent by email and regular mail and paper copies were sent to forest owners who had not responded to the first send out.

All three questionnaires contained an identical set of questions to assess changes in forest owners' attitudes over time. Questions were about individual concern about climate change, personal perception of climate change risks and impacts, resilience of forest property, personal knowledge, and trust in climate science (Table 5.1). Questions were formulated as statements and forest owners were asked to respond on a five-point Likert scale. Similar questions have been used in previous research on individual engagement with adaptation among forest owners in Sweden (Vulturius et al. 2018).

The first and third questionnaires also contained questions about forest management. Owners were asked what forest management options they had taken in the ten years before the first focus group meeting, and between the first meeting and spring 2018 four-and-a-half years later (Table 5.3). Forest management options included those that were discussed during the second and third focus group meeting.

The third questionnaire also asked forest owners to attribute recent changes in their forest management to different factors, including their participation in the focus group meetings (Table 5.4). This question was asked to avoid Type 1 errors in concluding that reported changes in behaviour were caused by forest owners' participation in the communication process.

Non-parametric tests of significance were used to assess differences in forest owners' attitudes about climate change (Table 5.1), as the data was on an ordinal scale and tended to be skewed. Friedman's ANOVA test was used to assess whether there were overall differences in the variance of forest owners' attitudes between all the questionnaires. The Wilcoxon signed-rank test was used to examine the significance of differences between pairs of questionnaires (Table 5.2), including the effect size expressed in r value. Values of 0.10 – 0.30 indicate a weak effect of the communication process on forest owners' attitudes about climate change, 0.30 – 0.50 indicate a moderate effect and 0.50 – 1.00 indicate a strong effect (Cohen 1992). The Friedman´s ANOVA test and the Wilcoxon signed-rank test are designed for non-parametric data from participants that have responded to the same questions more than once (Field et al. 2012) and have been used in previous research to examine the long-term effect of communication on individual engagement with climate change (Howell 2014). These tests are also designed to handle small sample sizes such as in this study (Field et al. 2012).

To examine changes in individual forest management (Table 5.3), the McNamer test for non-parametric, repeated-measure data was used (Field et al. 2012). The test compares the proportion of forest owners who had taken a certain forest management option in the ten years before the focus group meeting (until T-0) to those who taken that same option since the first meeting (between T-0 and T-2). All the data was analysed using the statistical software R (R Core Team 2015).

5.3 Results

Results of the qualitative data analysis

This section describes the results of the analysis of interviews conducted six months after the third and final focus group meeting. Results show that forest owners´ general experience with the focus group meetings was positive. More than seventy percent of forest owners commented favourably on the structure of the meetings and the scientific presentations. They appreciated the opportunity to learn and discuss scientific knowledge about climate change with scientists and other forest owners and exchange personal experiences with risks and forest management options. Negative comments were few and concerned primarily the practical value of the scientific information that was presented to them.

The analysis of the interviews also suggests that at least half of the owners had become more aware of climate change and more interested in adaptation. A quarter of forest owners said

that the knowledge that was presented to them strengthened their already existing perception of climate change risks. Around 20 percent of forest owners stated that their level of awareness and interest had not increased because they were already highly aware of the issue. Ten forest owners reported that they had started to more actively search for information about climate risks and adaptation options and that they were paying more attention to changing weather and climate conditions and changes in their own forest. Only two participants said that their level of awareness and interest had not changed at all.

In terms of personal assessment of risks, more than a third of forest owners remarked that they continued to consider storms as one of their key concerns even though the scientific data that was presented to them did not suggest any observed increase in wind intensity or storm frequency. Four forest owners also said that they were surprised to learn that climate models anticipated an increase in precipitation when they had personally experienced very dry conditions in the past few years. Forest owners from the north of Sweden also commented that they expected climate change to have some positive effects in terms of longer growth periods and that the exchange with scientists had helped them to a more holistic understanding of the consequences of climate change.

> "We have earlier focused a lot on the positive impacts of climate change. A Mediterranean climate isn´t exactly something you are afraid of; you can see that as an opportunity and not as a risk. But thanks to these meetings we have gained more insight into the consequences, how negative they can be, and how likely they are." (Forest owner from the north of Sweden)

Results from the interview analysis paint a complex picture of how meetings with scientists had influenced forest owners' trust in climate science. Almost 50 percent of forest owners opined that scientific knowledge about forestry, including how climate change will affect it lacks credibility and practical value. Instead of simply adopting new scientific information, forest owners explained that they would rely on their own judgements and on the opinions of experienced forest owners and other trusted advisors before making any changes to their forest management approach.

> "With all respect to researchers, but it's simply not enough to be a theorist and to have research reports. […] I like to listen to researchers, but I also question them sometimes. I don´t know what climate change will look like, but I like to listen to the old and experienced owners before I make my decisions" (Forest owner from the south of Sweden)

More than half of forest owners also reported that they had struggled to make sense of climate scenarios, statistical numbers and scientific information about appropriate forest management options to mitigate climate risks. While around a quarter of forest owners reported that having the opportunity to discuss with scientists how they conduct their research had improved their trust in them, five felt that the scientific uncertainty of climate models made them less credible.

Results also suggest that trust in climate science depends on personal belief in and experience with climate change. Eight forest owners stated that they have been observing changes in local weather and forest conditions and that the focus group meetings had confirmed them in their belief that these changes are linked to climate change.

> "I have learned [from the focus group meetings] that we need to adapt. You got to learn a completely different way of doing forestry. Something that didn´t grow here 10, 20 or 30 years ago is growing a lot now. I realized that when I updated my forest management plan from 15 years ago this summer [after the focus group meetings]" (Forest owner from the north of Sweden)

To improve trust in climate science and engage more forest owners in climate change adaptation, forest owners recommended that scientists should communicate their knowledge through existing and trusted information channels such as forest owner associations, professional forestry magazines, governmental agencies and industry associations. A quarter of forest owners also reported that they had shared their focus group experience with members of forest owner associations to which they belong.

Based on the qualitative data, is difficult to assess if, and how, forest owners' perception of their ability to adapt to climate change had changed due to their participation in focus group meetings. Those forest owners that felt better prepared to deal with climate change also reported that they had already been very aware of the issue before they participated in the focus group meetings. Some forest owners highlighted that the scientific knowledge that they received had helped them frame the issue and make sense of personal observations of changing weather conditions and extreme events.

> "I think that it [my capacity to adapt to climate change] has improved incredibly. As I said earlier, I have gotten headlines why things are happening … I have gotten a little more evidence for things that you can observe. And this makes you look at the forest in a completely different way." (Forest owner from the north of Sweden)

The qualitative data analysis also show that forest owners' attitudes toward adaptation and risk-mitigating measures is affected by a combination of factors, besides their participation in the focus group meetings, such as recent experiences with extreme events, conversations with other forest owners, information from forestry professionals, and media reports.

More than half of forest owners said that they would take climate change into greater consideration in their forest management in the future. Around a third of forest owners said that discussions had confirmed their already existing opinion about the need for adaptation. Forest owners mentioned that a stronger focus on pre-commercial thinning and cutting, and changes to tree-species mixture and diversity were good options to address risks from storms and climate change. Other changes to forest management they were considered relevant for climate adaptation were improvements to drainage ditches and forest roads to deal with increasing precipitation.

> "I have developed a new forest management plan since [the third focus group meeting]. The aspects that we discussed have influenced the way I manage my forest in terms of dealing with storm damages and the very difficult issue of rising water levels and drainage" (Forest owner from the south of Sweden)

Only two forest owners reported that they had made changes at least in part because of their participation in the focus group meetings. One forest owner in Northern Sweden mentioned that he had used a semi-conventional approach to final felling by preserving all broad-leafed trees. The other forester had made changes in the diversity of tree-species by planting more pine and broad-leaved trees, and by paying closer attention to local soil conditions during the replanting of recently harvested forest areas.

Results of the quantitative data analysis

This section presents the outcomes of the quantitative data analysis of the three questionnaires that forest owners completed before and after the end of the communication process. Table 5.1 offers an overview of forest owners' views on climate change before the first focus group meeting (T-0), immediately after the end of the third meeting (T-1) and four-and-a-half years after the first meeting (T-2). The table also contains results from the Friedman's ANOVA tests for differences in forest owners' views on climate change over the three different points in time.

Table 5.1 shows that the share of forest owners who were concerned about the risk of climate change for their forest decreased significantly from 37% before the first focus group

meeting, to 34 percent immediately after the last meeting, and to 20 percent in Spring 2018. The analysis also found a statistically significant decrease in the share of forest owners who considered the risk of climate change for their own forest to be serious. Furthermore, the analysis also shows a considerable, and close to statistically significant (p-value <0.10), increase in the number of forest owners who believed that they had enough knowledge to adapt their forest to climate change and who found climate science to be trustworthy.

The results also show, although not statistically significantly, that over the course of four-and-a-half-years, forest owners became less concerned about the global risk of climate change and considered the global impacts of climate change to be less serious. The share of forest owners that thought that they should take adaptive action increased considerably between the first and the final focus group meetings, but decreased from then, although to a level higher than before the communication process had started. Forest owners' opinions about the resilience of their forest to cope with climate change impacts remained largely unchanged. Owners also remained divided about the question if climate change would have negative rather than positive consequences for their property.

Table 5.1: Overview of changes in forest owners' views on climate change[1]

	Percent agreeing			Friedman's ANOVA		
Statement	**T-0**	**T-1**	**T-2**	**χ2 value**	**df.**	**p value**
I am very concerned about the global risk of climate change	57	60	43	2.240	2	.326
I am very concerned about the risk of climate change to my own forest	37	34	20	16.717	2	.000
I consider the global risk of climate change to be very serious	80	77	66	2.250	2	.325
I consider the risk of climate change to my own forest to be very serious	39	33	22	22.270	2	.000
I consider the consequences of climate change for my forest to be negative rather than positive	28	22	25	2.218	2	.330
I believe that my own forest is resilient enough to cope with climate change	43	49	43	1.153	2	.552
I believe that I have enough knowledge to adapt my forest to climate change	22	22	31	5.647	2	.059
I consider climate science to be trustworthy	46	47	57	4.914	2	.086
I need to take climate change into greater consideration	54	69	60	3.714	2	.156

[1] Only includes responses from forest owners that respond to all three questionnaires. N: 35

Table 5.2 shows the result of the Wilcoxon signed-rank test of the significance of differences between pairs of questionnaires. The test of the first pair of questionnaires (T-0 and T-1)

assesses short-term changes in forest owners' views on climate change. Results show no statistically significant changes (p-value <0.05) in forest owners' attitudes related to climate change between the first and last focus group meeting. However, the analysis does suggest that observed short-term increases in the share of forest owners who believed that they had sufficient knowledge to adapt their forest to climate change and who recognized the need to take adaptation measurers were close to being statistically significant (p-value <0.05).

The quantitative data analysis also suggests that long-term changes in forest owners' views about climate change are more pronounced than short-term changes. The two columns on the right-hand of Table 5.2 show the results for the Wilcoxon signed-rank test for the second pair of questionnaires (T-0 and T-2) that are four-and-a-half years apart. This analysis supports the Friedman's ANOVA analysis and shows that the share of forest owners who were concerned about climate change and its risks for their own forest had decreased significantly over the long-term. The r values also show the observed decrease in personal concern and risk perception was medium to large. Results also indicate that, over the long-term, the communication process had a significant, moderately strong and positive effect on forest owners´ belief in having enough knowledge to adapt to climate change and trust in climate science, which complements the findings of the Friedman's ANOVA analysis.

Table 5.2: Short-term (T0-T1) and long-term (T0-T2) changes in forest owners' views on climate change[1]

	Wilcoxon signed-rank test of comparison of T-0 and T-1		Wilcoxon signed-rank test of comparison of T-0 and T-2	
Statement	**p value**	**r value**	**p value**	**r value**
I am very concerned about the global risk of climate change	.419	.13	.563	.18
I am very concerned about the risk of climate change to my own forest	.864	.00	.007	.43
I consider the global risk of climate change to be very serious	1.000	.00	.151	.23
I consider the risk of climate change to my own forest to be very serious	.127	.24	.000	.56
I consider the consequences of climate change for my forest to be negative rather than positive	.187	.22	.251	.20
I believe that my own forest is resilient enough to cope with climate change	.554	.10	.721	.11
I believe that I have enough knowledge to adapt their forest to climate change	.051	.31	.022	.37
I consider climate science to be trustworthy	.083	.28	.028	.38
I need to take climate change into greater consideration	.053	.31	.362	.14

[11] Only includes responses from forest owners that respond to all three questionnaires. N: 35

Results also suggest that forest owners that had participated in the workshop eight months after the last group meeting did not show as much of a decrease in awareness about climate change at T-2. More than a third of these forest owners continued to be concerned about the impact of climate change on their own forest and more than 70 percent stated that they needed to take climate change into greater consideration.

The survey also supports the findings of the interviews about personal experiences with changing weather conditions and an increasing belief in climate change. Before the first focus group meeting, 59 percent of forest owners stated that they had observed changes in local weather conditions in the last thirty years, including two who had suffered from recent storms. After the last focus group meeting, the share had increased to 77 percent forest owners. This increase in belief in personal experience with climate change was statistically significant ($\chi 2$ value 4.166, p-value .014). During focus group meetings, many forest owners mentioned that they had suffered from a series of storms that affected Sweden in the winter of 2013/2014, during the time of the meetings. In the third questionnaire, around half of forest owners responded that they had observed changes in local weather and climate since the last focus group meeting, but none reported storm damages since then.

Table 5.3 shows long-term changes in personal forest management. It compares the share of forest owners who had taken certain forest management options in the ten years before the focus group meeting (until T-0) to those who had taken the option since the first focus group meeting (between T-0 and T-2). The table also contains the results of the McNamer $\chi 2$ test of the differences in the proportion of forest owners who had taken certain forest management options.

Results show that statistically fewer forest owners had taken local conditions into greater consideration during planting and final felling. The number of forest owners who had made improvements to drainage ditches and purchased insurance had also fallen significantly. The share of forest owners who had chosen to intensify pre-commercial thinning and cutting had also decreased, albeit not at a statistically significant level. An increasing number, although not statically significant, of forest owners had taken measures against pests and applied salvage cutting and reforestation to rectify storm damages.

Table 5.3: Changes in personal forest management[1]

	Percentage of positive responses		McNamer χ2 test		
Risk management options	**Until 10 years before T-0**	**Between T-0 and T-2**	**χ2 value**	**df.**	**p value**
Taking local conditions into greater consideration during planting or final felling	70	49	4.57	1	.033
Shorter rotation period between planting and final felling	22	32	2.00	1	.157
Increasing tree-species mixture and diversity	22	22	0.00	1	1.000
Harder pre-commercial thinning and cutting	59	46	2.27	1	.132
Forest management approaches that avoid clear cutting (e.g. continuous cover forest management	12	12	0.00	1	1.000
Taking measures against insects and fungi	12	26	1.92	1	.165
Improvements to drainage ditches	60	47	9.00	1	.003
Salvage cutting and reforestation after storms	33	42	0.60	1	.439
Purchase of insurance	65	27	10.71	1	.001
Investment into new equipment and roads	23	19	0.08	1	.781

[1]Only includes responses from forest owners that responded to both questionnaires. N: 37

Table 5.4 shows responses from forest owners to the question about how important certain factors were when they took forest management decisions since the first focus group meeting (between T-0 and T-2). This question was asked to avoid the conclusion that any observed change in forestry-related behaviour had resulted from forest owners' participation in the focus group meetings. The question also helps to better understand forest owners' decision-making.

Table 5.4: Self-reported influence on personal forest management decisions[1]

Factors that influenced forest owner management decisions between T-0 and T-2	**Percentage of forest owners that said that these factors were important**
Advice from extension services	53
Participation in the communication process	50
Personal knowledge and experience	63
Other forest owners	29
Forest management plan	38
Professional forestry literature	34
Other seminars, courses or study circles about climate change and forestry	32

[1] Only includes responses from forest owners that respond to the last questionnaire. N: 41

The data illustrated in Table 5.4 shows that for most forest owners, personal knowledge and experience was important when they took forest management decisions. Advice from extension services and participation in the focus group meetings was important for around half of forest owners. Forest management plans and professional forestry literature was

considered important by slightly more than a third of forest owners. Less than a third of owners thought that other forest owners or participation in other communication processes about climate change have had a considerable influence on their forest management in the past four-and-a-half years since the first focus group meeting.

5.4 Discussion

The quantitative data of this study suggests that after participating in the communication process forest owners on average had gained more trust in climate science over the short- and long-term. The qualitative data indicates that this was due to the participatory nature of the focus group meetings, which allowed forest owners to discuss with scientists their findings and the methods behind them. Broadly speaking, these findings supports the assumption that science-based stakeholder dialogues can improve understanding about climate change and trust in climate science (Jönsson and Gerger Swartling 2014).

However, results from the interviews also show that after participating in the climate communication process, almost half of all forest owners continued to have considerable reservations against scientific knowledge in general and climate science in particular. This suggests that science-based stakeholders dialogues have only limited potential in changing the opinions of individuals that distrust climate science. Instead, interviews showed that forest owners rely strongly on their own judgements and the opinions of other forest owners and experts before making any changes to their forest management approach. This could suggest that peers may be better than experts in building trust in climate science and in promoting engagement with adaptation amongst individuals that are dismissive and doubtful of climate science (Moser 2016).

The quantitative data analysis also suggests that over the long-term the communication process had a moderate effect on forest owners´ belief in having enough knowledge to adapt to climate change. Interviews also indicate that scientific knowledge presented during the focus group meetings had helped participants to make sense of their personal experience with changing weather, climate and forest conditions. These results indicate that communication can improve individuals' sense of self-efficacy by disseminating scientific knowledge that is tailored to the experiences and needs of its target audience (Bostrom et al. 2013).

The results also highlight the close and potentially mutually reinforcing relationship between personal experience with changing weather and climate conditions, belief in personal experience with climate change, and intentions to act (Blennow et al. 2012). At the end of the focus group meetings, the share of forest owners who thought that they had observed climate change and that they had to take adaptive measures had increased significantly. These findings indicate that climate communication can strengthen personal belief in climate change and increase engagement with adaptation by helping individuals link their personal experience with weather, climate and extreme events to climate change.

Unexpectedly, the quantitative data analysis also shows that four-and-half-years after the first focus group meeting, fewer forest owners were concerned about climate change and fewer thought that it would pose serious risks for their forest. This long-term decline in concern and risk perception can be interpreted in different ways. It could indicate that forest owners responded to the communication process by discounting the risk of climate change (Weber 2010), and that climate scientists were not successful in highlighting the temporal and spatial proximity of climate change (Brügger et al. 2015). The results from the interviews also show that several forest owners found climate models to be too uncertain. These findings support earlier research that had found that public perceptions of scientific uncertainty are one of the main challenges for climate communication to promote cognitive and behavioural change (Moser 2014).

Another possible reason why forest owners became less concerned about the risk of climate change could be lack of personal experience with storm damages since group meetings had ended. Between December 2016 and spring 2018 when the third questionnaire was sent, the Swedish Meteorological and Hydrological Institute reported no major storms. It can be assumed that forest owners' concern about climate risks increased in response to the drought and forest fires Sweden suffered which took place after the last questionnaire was collected.

Results from both the qualitative and quantitative data analysis also shows that most forest owners believed they had to take climate change into greater consideration. Data from the final questionnaire also shows that forest owners' opinion about the need to take adaptive action had not changed even though their concern about climate risks had decreased.

However, forest owners´ unchanged perception of the need to take adaptive action was not reflected in their forest management. While results from the interviews suggest that forest

owners were interested in active adaptation measures such as diversifying tree-species mixture, intensifying pre-commercial thinning and cutting, improving drainage ditches and investing in roads, the share of forest owners who had taken these measures after the climate communication process had not increased significantly. Instead, the quantitative data suggests that on average forest owners had not changed their forest management practices since the first meeting. One exception was improvement to drainage ditches which thirteen percent fewer forest owners had done between the first meeting and the survey in spring 2018 compared to the ten years before the first meeting.

Furthermore, the data also indicates that forest owners don´t change how they managed their forests exclusively based on a single source of information. Rather, they rely on their own experiences and judgments and other sources of expert and local knowledge (André et al. 2017). This highlights that the communication and adoption of scientific knowledge is a complex socio-cognitive process that depends on how people make sense of the perceived empirical credibility (Asplund 2018), practical value (Vulturius and Gerger Swartling 2015) and social acceptability of climate science (Kahan et al. 2012).

5.5 Conclusion

This study examined the effect of participatory, science-based climate communication on individual engagement with climate change adaptation among forest owners in Sweden. It was based on the analysis of qualitative and quantitative data about changes in cognitive and behavioural factors over a four-and-a-half-year long period. The data was collected at four different moments in time before and after forest owners had participated in a series of focus group meetings and workshops with scientists and their peers.

In conclusion, this study suggests that climate communication has limited direct effect on individual engagement with adaptation. Instead, results highlight that individuals are influenced in how they view climate change and how they respond to it by a diverse set of cognitive, behavioural and external factors that exists alongside climate communication. This makes it very difficult to point to any direct effects of climate communication on how people think, feel and act on climate change. However, rather than dismissing communication for its limited success in changing awareness and action on its own, researchers and practitioners should learn how to better tailor communication interventions to the personal experiences and decision-making needs of their target audience and involve trusted peers and information channels.

Beyond its empirical results, the study also offers insights into how to operationalize and measure outcomes of communication with the objective of individual engagement with climate change (McEvoy et al. 2018). The study shows the potential of using qualitative and quantitative data in tandem to capture a broader spectrum of the short- and long-term effects of climate communication on individual cognitive and behavioural engagement. Future research on climate communication should link up with the literature on learning in natural resource management which has highlighted the importance of skill-development and that is increasingly concerned with the question how interventions, such as climate communication, can built social relations and improve environmental management and planning under rapid global change (Suškevičs et al. 2018).

Furthermore, the study also highlights the great value of before-after studies of climate communication to draw verifiable conclusions about the lasting effect of communication for climate change action (Howell 2014). The study´s longitudinal design combining quantitative and qualitative data and methods should be used and refined in future studies to enable more rigorous assessments of the different outcomes of climate communication, when they occur, under what conditions, and how and when different forms of climate communication can be used most effectively (Gerlak et al. 2018).

Chapter 6: The influence of climate change communication and personal forest values on engagement with adaptation among forest owners in Sweden

6.1 Introduction

Climate change is expected to have profound impacts on forests and their owners in Sweden. Storm Gudrun in 2005 which felled 250 million trees and caused damages of 2,5 billion Swedish kronor (235 million Euro) (Lidskog and Sjödin 2014) highlighted the risk of climate change to spruce-dominated forestry in Sweden (Valinger and Fridman 2011). Climate change is expected to exacerbate well-known risks, such as storms and windthrow, as well as from lesser-known, emerging risks, including drought and forest fires (Lindner et al. 2014) pests and invasive species (Jönsson and Bärring 2011) poorer ground conditions (Lindner et al. 2010) and biodiversity loss (Felton et al. 2016). Recent research also suggests that increased frequency and intensity of disturbances may cancel out increased growth potential (Reyer et al. 2017).

Forest owners in Sweden face the difficult task of understanding how climate change will affect familiar and unfamiliar risks, and which forest management options are effective in adapting to changing climatic conditions (Keskitalo et al. 2016). Despite increasing scientific knowledge about climate risks and adaptation options, previous research has shown that most forest owners in Sweden are not concerned about climate change (Eriksson 2014), and that they do not intend to take adaptive action in the near future (Vulturius et al. 2018). Forest owners' perceptions about climate change risks and preferences for forest management options may also depend on their personal appreciation of economic, environmental or recreational forest values (Nordlund and Westin 2010). As more than half of Sweden's productive forest is owned by around 330,000 non-industrial private forest owners (Swedish Forest Agency 2014), the ways in which the Swedish forest sector will adapt to climate change greatly depend on how individual owners appraise climate change risks and adaptation options.

Forest owners in Sweden act relatively independently in managing their forests, (Lindahl et al. 2017) and there is no official political strategy for climate change adaptation of the forestry sector (Keskitalo et al. 2016). In light of this situation, the Swedish Forest Agency has

been using communication campaigns to raise awareness about climate risk and adaptation options (Nordström 2014). Similar projects have been conducted by forest services in other parts of the world including Forest Change, the Canadian Forest Service program on adaptation on climate change (NRC 2019); and Adaptation Partners, a science-forest management partnership for climate adaptation supported by the US Forest Service (US Forest Service 2019). The theory and practice of communicating climate science with the purpose of promoting individual and collective awareness, deliberation and action — climate change communication — have become an established academic domain in the last 10 years (Nerlich et al. 2010; Moser 2016).

This study has the aim of improving the scientific understanding of how climate change communication can promote personal engagement with adaptation (Moser 2010, 2014; Gifford et al. 2011). Based on the scientific literature, we assume that individual engagement with adaptation is the product of intrapsychic processes including cognitive appraisal of climate change risks and adaptation options, affective responses, motivated reasoning based on personal values (Grothmann and Patt 2005; Swim et al. 2009; Bradley and Reser 2017), and social processes, such as communication (Moser 2014) that amplify interpersonal discourse, learning and action about climate change (Renn 2011).

We ask if communication changes forest owners' general views related to adaptation, their assessment of specific climate-related risks, and their preference for forest management measures to adapt to climate change. We also ask if owners' forest-related values influence their views, perceptions and preferences related to adaptation. Furthermore, we assess if communication changes the relationship between values and personal views, perceptions and preferences regarding adaptation. To answer these questions, we implemented a deliberation-orientated climate change communication project drawing from the concept of science-based stakeholder dialogues (Welp et al. 2006a), and used a longitudinal panel design based on previous research on short- and long-term effects of climate change communication (Howell 2014).

Climate change communication for promoting individual engagement with adaptation

According to the American Psychological Association, communication is a social process that influences how people think, feel, intend to act, and eventually act on climate change (Swim et al. 2009). In this paper, we assume that climate change communication has the objective to increase individual engagement with the topic (Wibeck 2013). We follow a general

definition of individual engagement as “a personal state of connection with the issue of climate change […] concurrently comprising cognitive, affective and behavioural aspects” (Lorenzoni et al. 2007, p. 446). Individual engagement is required at all three stages of the adaptation process ranging from understanding, planning and managing (Moser and Ekstrom 2010). Given that previous research has shown that most forest owners in Sweden struggle to understand and plan for adaptation (Lidskog and Sjödin 2014; Vulturius et al. 2018), this study focuses on the first two stages of the adaptation process.

How effective climate change communication is in promoting individual engagement with adaptation depends on its influence on intrapsychic processes that determine individual perceptions and behavioural intentions (Swim et al. 2009). Earlier research on forest owners in Sweden has pointed to several intrapsychic factors that climate change communication must influence if it wants to achieve greater individual engagement with adaptation. Blennow et al. (2012) found that personal beliefs and perceptions of local effects of climate change can explain adaptative behaviour among forest owners, while Vulturius et al. (2018) found a connection between forest owners’ intentions to take adaptive action and their perceptions of the severity of climate change impacts, trust in climate science, and belief in having enough knowledge.

Insights from earlier studies on forest owners in Sweden also reflect the broader literature on public perception and action on climate change, which suggests that adaptation is only likely when people feel concerned about climate change impacts (Roeser 2012); trust climate science (Goodwin and Dahlstrom 2014); believe in their personal ability to adapt (Niles et al. 2016), and in the efficacy of adaptation options (Singh et al. 2017); and when people perceive that climate change threatens something they perceive to be valuable (McDonald et al. 2015). Previous research involving Swedish forest owners also suggests that achieving greater individual engagement with adaptation can be aided by a deliberation-based approach to climate change communication (Jönsson and Gerger Swartling 2014; Vulturius and Gerger Swartling 2015). This confirms the general trend from the transmission-oriented approach to the deliberation-orientated approach to climate change communication that has been observed in the literature (Pearce et al. 2015; Ballantyne 2016). In practice, this means promoting engagement with adaptation by a means of communication in which participants take active part in the learning process, rather than aiming solely to improve individual understanding of climate change (Moser and Dilling 2011; Moser 2014).

Communication based on participation and dialogue have been found to be successful in deepening understanding, fostering empathy, changing attitudes, and increasing receptiveness to climate change policies (Moser 2016). Long-term engagement and relationship building have identified as key factors to overcome the deficiencies of non-participatory models of climate change communication, and to achieve trust-based relationships between scientists and the audiences they seek to educate (Cook and Overpeck 2019).

The influence of personal values on individual engagement with adaptation

There is increasing recognition that individual engagement with the issue of climate change is also influenced by motivated reasoning: the systematic bias that occurs when individuals understand information in favour of pre-existing values, beliefs and attitudes (Lodge and Taber, 2013). The literature documents the influence of worldviews and political ideologies on public opinion about the causes of climate change (Kahan et al. 2012), risk perception (van der Linden 2015), trust in climate science (Whitmarsh 2011) and support for mitigation action (Hart et al. 2015). Correspondingly, values-driven motivated reasoning has also been found to be a barrier to individual engagement with adaptation (Taylor et al. 2014; Niles et al. 2016; Akerlof et al. 2016). Thus, this study follows the values-based approach to research about adaptation (O'Brien and Wolf 2010) acknowledging that climate change is a socially amplified phenomenon (Whitmarsh and Lorenzoni 2010) and that perceived vulnerability to climate change impacts, perception of climate change risks, and personal opinion about adaptation options hinge on people's values, beliefs and motivations (Adger et al. 2009; Wolf et al. 2013).

Following earlier work by McFarlane and Boxall (2003), this study assumes that values driving motivated reasoning are part of a hierarchical intrapsychic processes that influences beliefs and attitudes towards climate change risks and adaptation. Basic values are general guiding principles in people's lives that form the foundation of specific values, beliefs and attitudes that allow them to act on these values in a certain domain (Schwartz 1992), such as forest management or climate change adaptation. This study focuses on personal forest values: specific values that reflect why people value forests, including the value for humans (e.g. production) and the biosphere (e.g. nature conservation) (Eriksson 2018).

The assumption that personal forest values influence individual engagement with adaptation is based on earlier research which has shown that these domain-specific values have a stronger influence than basic values on forest management (Nordlund and Westin 2010).

Research involving forest owners in Sweden (Kindstrand et al. 2008) and elsewhere (Wiersum et al. 2005) has found that forest owners have diverse sets of personal forest values — e.g. timber production, environmental protection or recreation — that influence their assessment of risks (Eriksson 2014) attitudes towards forest management measures (Nordlund and Westin 2010), and capacity to adapt to climate change (Blanco et al. 2015).

In the Swedish forest sector, shared values form the basis of a liberalised regulatory system (Andersson et al. 2018). The revision of the national forestry regulations in 1993 lifted regulations on forest management, giving forest owners greater autonomy in how they manage their forests (Appelstrand 2012). The new legislation also established an environmental goal in parallel with the long-standing goal of maintaining high wood production for economic gain (Lindahl et al. 2017). Forest owners are now expected to improve environmental conditions while maintaining high wood production - a policy known as “freedom with responsibility” (Appelstrand 2012).

Even though environmental and economic goals are equally important according to the revised legislation, maximizing wood production for economic gain remains the dominant goal in the Swedish forest sector (Andersson et al. 2018). Research suggests that forest owners who strive for short-term economic gain and follow the production-orientated rationale are less concerned about the long-term consequences of climate change (Lidskog and Sjödin 2014; Lidskog and Löfmarck 2015). Environmental values, on the other hand, have been shown to influence environmental risk perception (Slimak and Dietz 2006), and research also suggests that personal belief in climate change is an important factor for climate change adaptation among Swedish forest owners (Blennow 2012).

Less is known about how personal forest values influence preferences for adaptation options. Andersson and Keskitalo (2018b) have argued that under the current forest sector paradigm, business-as-usual forest management options, such as earlier logging and better choice of plant material, remain the logical climate adaptation choices for most forest owners because such measures do not challenge the present production system and economic rationale. However, forest management that aims to achieve multiple objectives has been found to provide the best basis for adaptation in Sweden because it maximises resilience and provision of ecosystem services (Blanco et al. 2017a).

Communication affecting the influence of personal values and individual engagement with adaptation

Given the evidence that motivated reasoning influence public risk perception and support for climate policies (Hart et al. 2015), a growing body of research is examining whether communication can affect the influence of values on individual engagement with climate change. Van der Linden et al (2019) showed that providing people with information about the scientific consensus about climate change helped overcome the influence of political ideology on personal views on climate change. Similarly, Akerlof et al. (2016) showed that deliberations with climate scientist increased knowledge and concern about climate change impacts among participants with a worldview predisposing them to lower risk perceptions. The same study also found that the influence of worldviews was less important when participants were asked to assess climate change risk to one's own home or property. This also supports research by Chu and Yang (2018) that the effect of personal worldviews and political ideology declined when climate change impacts were portrayed as a proximal and familiar risks — e.g. storm risk in the forest sector.

However, there is also research suggesting that communication's mediating influence on motivated reasoning and on individual engagement with climate change is short lived (Kerr and Wilson 2018).Critiques have surfaced regarding the premise that providing people with knowledge about climate change leads them to the same conclusions, irrespective of or despite their pre-existing values (Kahan and Carpenter 2017). Even less is known about how and whether climate change communication can affect the influence of domain-specific values, such as forest values, on personal views, perceptions and preferences regarding adaptation.

This study tests the following hypotheses:

1) Climate change communication influences forest owners' general views related to adaptation, their appraisal of climate change risks, and their preferences for forest management options.
2) Personal forest values influence forest owners' general views related to adaptation, appraisal of climate change risks, and preferences for forest management options.
3) Communication affects the influence of personal forest values on forest owners' general views related to adaptation, appraisal of climate change risks, and preferences for forest management options.

6.2 Materials and Methods

Climate change communication with forest owners in Sweden

To answer the question of whether climate change communication can alter perceptions and attitudes related to adaptation, this study conducted its own climate change communication project. The project involved 45 private forest owners in Sweden, climatologists from the Swedish Meteorological and Hydrological Institute (SMHI), a researcher from the University of Lund specializing in forest management and climate change, and two of the authors of this paper.

Purposive sampling was used to select the forest owners who participated in the climate change communication project. Sampling of project participants had the aim of covering different climatic and ownership characteristics. In general, forest owners in the south experience milder temperatures, have a comparatively higher share of deciduous trees, and own on average less forest land than their peers in north and central Sweden. Owners in north and central regions, by comparison, face colder conditions, have a higher share of coniferous trees, and own on average more forest land. To identify and select forest owners whose properties match this diverse set of characteristics, contacts were made with local and regional organizations such as the Swedish Forest Agency, forest owner associations, consultants, and wood buyer/sawmill companies.

Forest owners who participated in this study came from counties located in the south (Skåne), centre (Gävleborg) and the north (Jämtland and Västerbotten) of Sweden. They owned between 20 hectares (ha) and more than 1000 ha of forest land. Nearly one-third of participants, 30 percent, were female. Owners ranged in age between 30 and over 80. Almost all of them had their forestry certified credentials, according to the Forest Stewardship Council (FSC) or the Programme for the Endorsement of Forest Certification (PEFC) standard. In all, 36 percent said that they were dependent on income from forestry for their livelihoods.

In keeping with the trend towards more deliberation-orientated forms of climate change communication (Pearce et al. 2015), the climate change communication project in this study was designed as a participatory science-based stakeholder dialogue (Welp et al. 2006a). Drawing from a previous climate change adaptation project that used this methodology (Welp et al. 2006b), the communication project encompassed a series of focus group meetings and one workshop. The overall objective of the project was to enable the sharing of knowledge, perspectives, reflections and learning among scientists and forest owners, and

to gain greater insights into the complexities and realities of individual forest management (André et al. 2016).

There were seven focus groups, two in each county (except for Gävleborg, which had only one). Groups met on three separate occasions over a four-month period, starting in late November 2013, and ending in the beginning of March 2014. Two of the authors facilitated each meeting, which lasted about two and a half hours. A workshop held in Stockholm in November 2014 finalised the communication process. Participation in the focus group discussions was voluntary, and all participants agreed that their discussion would be recorded and exclusively used for research purposes.

The *first* focus group meeting introduced participating forest owners to the communication project, and initiated the group discussion about climate change, risk and adaptation measures. Focus group participants were asked to reflect and share their perceptions of current and future challenges and risks, as well as their experiences with forest management. Climate change was introduced by asking the owners about their initial thoughts and associations regarding climate change in general, and in relation to their forest specifically.

The *second* focus group meeting asked the question of what climate change means in the four different counties, and the implications for the forest sector in terms of climate impacts and adaptation options and needs. At the start of the meeting, a climate scientist from SMHI presented future climate scenarios for each of the four counties and explained how climate scenarios are developed. The presentation was based on an interactive web application (https://www.smhi.se/en/climate/climate-scenarios/sweden). Forest owners were given the opportunity to ask questions, and to discuss climate scenarios with the scientist from SMHI.

Also, during the second meeting, an ecologist from the University of Lund presented scientific knowledge about forest-related climate change risks, such as poorer ground conditions, bark beetles, or drought (Jönsson et al. 2013). The presentation also included information from previous and ongoing research about climate adaptation options, such as reactive measures (e.g. salvage cutting after storms), active measures (e.g. harder cleaning and pre-commercial thinning) and pro-active measures (e.g. adoption of alternative silviculture approaches that avoid clear cutting) (Jönsson 2013, 2015). Forest owners and the scientists then discussed the synergies and conflicts between different adaptation options and their practical implications. (Table 6.1 contains a list of measures that were presented and discussed during the focus group meetings.)

During the *third* and final focus group meeting, discussions about different types of forest management options and how they link to climate adaptation continued. Forest owners also discussed the roles and responsibilities of different actors in the Swedish forest sector to promote climate adaptation, and the matter of how climate science can be better communicated to gain greater credibility among forest owners. Half of the focus group participants also volunteered to take part in a *workshop* that took place eight months after the third focus group meeting. The workshop gave them the opportunity to reflect on the focus group meetings, and to exchange experiences and insights.

Data collection and analysis

This study draws from a set of three questionnaires that forest owners were asked to complete immediately before the first focus group meeting in November 2013 (T-0), immediately after the third and last focus group interview in March 2014 (T-1), and four-and-a-half years after the first focus group meeting in spring 2018 (T-2). Not all 45 forest owners who participated in the focus group interviews responded to each questionnaire. The response rate ranged from 78 percent to 73 percent depending on the individual question. The first two questionnaires were handed out in person. The third questionnaire was sent by email as well as by post if requested, or if forest owners had not left a valid email address. Two reminders were sent by email and by post, and paper copies were sent to forest owners who had not responded to the first mailing.

Table 6.1 displays the aspects measured by the questionnaire. The first questionnaire asked forest owners to rate how important different forest values are for them on a scale from one to five. The list of fifteen forest values was compiled based on previous research about forest owners in Sweden and elsewhere in Europe (Wiersum et al. 2005, Berlin et al 2006, Ingemarson et al. 2006, Nordlund and Westin 2010). All these studies have in common that they agree that forest-specific values guide forest management decisions and that forest owners hold values belonging to different value dimensions. Berlin et al (2006) and Wiersum et al (2005) focused on forest values related to recreation and tradition, including outdoor lifestyle, mushroom and berry picking, hunting, keeping local traditions and preserving forest landscapes. Ingemarson et al. (2006) considered a broader spectrum of forest values which, besides recreation and tradition, also consist of values related to production and economic gains, including income generation, timber production, tax planning, return on investment, as well as values related to environmental protection including nature conversation, water

conservation and soil conservation. Given that the debate about the Swedish forest sector's in climate change has historically focused on its ability to sequester carbon, we also include climate change mitigation and biofuel production to the list of values (Ulmanen et al 2015).

We grouped forest values into three different value dimensions: production and economic gain, environmental and climate action, and recreation and tradition. These broad categories have been identified in previous research by Nordlund and Westin (2010) and which used values similar to those used in this study. We then calculated an index score for each value dimension by adding up the rating for each forest value that belonged to it. Given the small number of cases, using more sophisticated statistical methods, such as factor analysis to group forest values, was not possible. However, to ensure that consistency between values and value dimensions, we calculated Kendall's tau correlation coefficients between the values and the index scores of the value dimension they were assigned to.

Table 6.1: Overview of the variables in the study

Factors	Questionnaire	Measurement
General views on climate change, climate science and adaptation	T-0	Concern about the global impacts of climate change, concern about the local impacts of climate change, seriousness of global risks of climate change, seriousness of global risks of climate change, assessment of the positive vs negative impacts of climate change, believe in forest resilience, believe in personal knowledge about climate change, trust in climate science, perceived need to take climate change into greater consideration
Forest values	T-0, T-1, T-2	**Production and economic gain:** Timber production, income generation, liquidity reserve, return on investment, tax planning **Environmental and climate action:** Environmental protection, water protection, soil protection, mitigating climate change, biofuel production **Recreation and tradition:** Outdoor lifestyle, mushroom and berry picking, keeping forestry tradition, hunting, preserving forest landscape
Perception of the severity of climate change related risks today and in 50 years	T-0, T-1, T-2	Storms, flooding, snow breakage, frost, damage due to poorer ground conditions, pests, loss of biodiversity
Preference for risk mitigating measures to adapt to climate change	T-0, T-1, T-2	**Reactive measures:** Salvage cutting and reforestation after storms **Active measures:** Taking local conditions into greater consideration during planting and final felling, shortening rotation periods between planting and final felling, increasing tree-species mixture and diversity, harder pre-commercial thinning and cutting, taking measures against insects and fungi, improvements to drainage ditches, salvage cutting and reforestation after storms, investment into new equipment and roads, having forest insurance **Proactive measures:** Forest management approaches that avoid clear cutting (e.g. continuous cover forest management)

All three questionnaires contained three identical sets of questions (see Table 1.1). The first set of questions, which has been used in earlier research (Vulturius et al, 2018), addressed general views on climate change, climate science and adaptation. Forest owners were asked

to rate, on a scale from one to five respond to statements about: the impacts of climate change globally and on their own forests, the seriousness of the risk of climate change globally and for their own forest, their belief in the resilience of their own forest to cope with the consequences of climate change, their level of trust in climate science, their personal level of knowledge about climate change, and their perceived need to take adaptive measures[7].

The questionnaire also asked forest owners about their appraisal of more specific climate-related risks (Table 6.1). These risks were selected from the scientific material presented during the climate change communication project. Forest owners were first asked to rate, on a scale from one to five, how serious they believe these risks are today, and whether they believe that these risks will become more serious in the next 50 years. The questionnaire also asked forest owners to select up to five of 11 forest management measures that they thought would be most effective in adapting their forest to climate change. Measures included those that were discussed during the second and third focus group meetings. The measures included reactive, active and proactive management options.

Given the small number of respondents, we used non-parametric statistical analysis to test our research assumptions (Field et al., 2012). We used the Wilcoxon signed-rank test to examine changes in forest owners' general views on adaptation and their assessment of climate-relate risks today and in the future between the first and last focus group meeting (T-0 and T-1) and between the first focus group meeting and four-and-a-half years later (T-0 and T-2).

The McNamer's χ^2 test was applied to test changes in the proportion of forest owners who considered certain forest management options to be effective for climate adaptation. Kendall's τ test was used to calculate the correlation between the three different value dimensions and general views on climate change and specific climate-related risks. Point-biserial correlation was used to test the correlation between value dimensions and preferences for forest management options. Changes in Kendall's τ test and point-biserial correlation test between T-0 and T-1, and T-0 and T-2 were calculated to assess the effect of

[7] E.g. one statement read: "I consider the risk of climate change to my own forest to be very serious." Forest owners responded on a scale from 1 = "strongly disagree" to 5 = "strongly agree".

communication on the relationship between value dimensions and personal views on adaptation, risk perception and management preferences.

The Wilcoxon signed-rank test, the Kendall's τ test and point-biserial correlation test all assume that input variables are on an interval scale. Responses to these input variables for these tests – general views on climate change, climate science and adaptation, forest values and forest owners' perception of the severity of climate change related risks today and in 50 years – were collected on a five-point Likert scale. We acknowledge that some have argued that the Likert scale response format consists of a set of ordered categories and that this would make mean, correlation, or other numerical operation applied to Likert scale data invalid (Jamieson 2004).

Yet, this study follows research by Norman (2010) which has shown that the Likert scale response format can produce interval data and that this data can be used to calculate means and conduct mean-based tests – like the Wilcoxon signed-rank test – even if the data is not normally distributed. We also consider the argument made by Carifio and Perla (2007) that Likert scales should consist of different items – such as responses to individual statements – to measure an underlying theoretical concept or emerging property. This study uses Likert scales to measure the concept of individual engagement with adaptation and forest values among forest owners.

The data from the questionnaires were analysed using the statistical software R (R Core Team 2015).

6.3 Results

Changes in general views related to climate change adaptation

Table 6.2 shows forest owners' general views on climate change before the focus group meeting (T-0), after the last focus group meeting (T-1), and four-and-a-half years after the first focus group meeting (T-2). It also shows the results of the Wilcoxon signed-rank test of the difference between responses at T-0 vs. T-1 and T-0 vs. T-2. The table includes the effect size of each correlation expressed in r values. Values of .10 – .30 indicate a weak effect; .30 – .50 indicate a moderate effect; and .50 – 1.00 indicate a strong effect (Cohen 1992).

Results show that before the climate change communication project, forest owners on average were not very concerned about the local impacts of climate change, and they didn´t consider the risks of climate change for their own forest to be very serious. Moreover, forest

owners were also uncertain whether climate change would have mostly negative or positive consequences for their forest. However, results also indicate that there was a relatively strong sense among forest owners to take adaptive measures.

Table 6.2: Changes in forest owners' general views related to adaptation[1]

	Mean (Standard Deviation)			Wilcoxon signed-rank test	
Statement	**T-0**	**T-1**	**T-2**	**T-0/T-1**	**T-0/T2**
I am very concerned about the global risk of climate change	3.64 (0.93)	3.82 (1.07)	3.51 (1.00)	r = .13	r = .18
I am very concerned about the risk of climate change to my own forest	3.29 (0.99)	3.28 (0.89)	2.71 (1.02)	r = .00	r = .43**
I consider the global risk of climate change to be very serious	4.17 (0.75)	4.17 (.78)	3.97 (1.01)	r = .00	r = .23
I consider the risk of climate change to my own forest to be very serious	3.39 (0.84)	3.19 (0.89)	2.72 (1.03)	r = .24	r = .56***
I consider the consequences of climate change for my forest to be negative rather than positive	2.88 (0.66)	3.03 (0.69)	3.03 (0.74)	r = .22	r = .20
I believe that my own forest is resilient enough to cope with climate change	3.31 (0.83)	3.46 (0.81)	3.43 (0.85)	r = .10	r = .11
I believe that I have enough knowledge to adapt my forest to climate change	2.64 (0.96)	2.92 (0.84)	3.06 (0.86)	r = .31	r = .37*
I consider climate science to be trustworthy	3.49 (0.88)	3.69 (0.83)	3.80 (0.87)	r = .28	r = .38*
I need to take climate change into greater consideration	3.71 (0.89)	3.97 (0.92)	3.54 (0.95)	r = .31	r = .14

[1] Only includes responses from forest owners that respond to all three questionnaires. N: 35
Significance codes: * p < .05, ** p < .01, *** p < .001

The analysis suggests that four-and-a-half years after the focus group meetings, forest owners had become less concerned about the impacts of climate change on their forest and considered the risk of climate change to be less serious. Results also indicate that after the focus group meetings, forest owners believed more strongly that they have enough knowledge to adapt to climate change, and they had greater trust in climate science. Furthermore, the analysis did not show that forest owners had become more convinced that they had to take climate change into greater consideration.

Changes in forest owners' appraisal of climate-related risks

Table 6.3 shows forest owners' perceptions of different climate-related risks before and after the climate change communication project, and the results of the Wilcoxon signed-rank test. Results show that before the focus group meetings, forest owners on average were most concerned about current risks of storms, pests and poorer ground conditions; they were least concerned about current risks from flooding, frost damage, drought and forest fires. Before

the climate change communication project, forest owners also believed that risks from storms, pests and poorer ground conditions would become more serious in the future.

Table 3.3: Changes in forest owners' perceptions of climate-related risks[1]

	Mean (Standard Deviation)			Wilcoxon signed-rank test	
Statement	**T-0**	**T-1**	**T-2**	**T-0/T-1**	**T-0/T2**
Storms – today	3.33 (0.99)	4.06 (0.75)	3.55 (0.94)	r = .61***	r = .24
Storms – change in 50 years	4.22 (0.72)	4.22 (0.69)	3.71 (0.89)	r = .00	r = .52**
Flooding – today	1.89 (0.92)	2.42 (1.25)	2.00 (1.16)	r = .39*	r = .12
Flooding – change in 50 years	2.69 (1.21)	3.09 (1.25)	2.69 (1.56)	r = .28	r = .03
Snow breakage – today	2.89 (0.95)	3.17 (1.03)	3.22 (1.07)	r = .30	r = .35*
Snow breakage – change in 50 years	3.40 (0.98)	3.31 (1.05)	2.97 (1.20)	r = .07	r = .31
Frost damage – today	2.37 (0.84)	2.40 (0.78)	2.40 (0.81)	r = .03	r = .03
Frost damage – change in 50 years	2.71 (1.13)	2.71 (1.07)	2.46 (0.89)	r = .01	r = .24
Drought and forest fire – today	2.43 (0.85)	2.63 (0.94)	2.86 (1.11)	r = .18	r = .37*
Drought and forest fire – change in 50 years	3.26 (1.12)	3.06 (1.08)	3.03 (1.12)	r = .18	r = .19
Damage due to poorer ground conditions – today	3.29 (0.96)	3.66 (1.03)	3.00 (1.11)	r = .36*	r = .20
Damage due to poorer ground conditions – change in 50 years	3.85 (1.21)	4.03 (0.83)	3.41 (0.89)	r = .14	r = .37*
Pests such as bark beetles or root rot – today	3.20 (1.02)	3.54 (0.92)	3.49 (0.74)	r = .31	r = .24
Pests such as bark beetles or root rot – change in 50 years	4.12 (0.95)	3.91 (0.93)	3.76 (0.89)	r = .22	r = .36*
Loss of biodiversity – today	2.83 (1.13)	2.86 (1.03)	2.69 (0.96)	r = .07	r = .16
Loss of biodiversity – change in 50 years	3.38 (1.04)	3.32 (0.94)	2.74 (1.11)	r = .07	r = .53**

[1] Only includes responses from forest owners that respond to all three questionnaires. N: 35
Significance codes: * p < .05, ** p < .01, *** p < .001

The analysis also shows that forest owners' appraisal of current storm risks increased immediately after the end of the last focus group meeting (T-1). There was, however, no significant increase in the assessment of current storm risks between T-0 and T-2. Over the same period, forest owners also became less convinced that storm risks would become more serious in the coming 50 years. A similar pattern can also be observed in the case of biodiversity loss, damage due to poorer ground conditions, and pests. In each of these cases, forest owners changed their perceptions significantly, and came to believe that these risks would become less serious in the next five decades. Results, however, suggest that appraisal

of current risks from snow damage, drought and forest fires changed even though these specific risks continued to be of comparatively little concern to forest owners.

Changes in forest owners' preferences for forest management options to adapt to climate change

Results about forest owners' preferences for different forest management options to adapt to climate change can be found in Appendix 12. Overall, results indicate that forest owners consider the following measures as the most effective ways to adapt to climate change: taking local conditions into greater consideration during planting and final felling; increasing tree-species mixture and diversity; undertaking harder pre-commercial thinning and cutting; and making improvements to drainage ditches.

Forest owners considered less conventional or more capital-intensive measures to be least effective in addressing climate change impacts; such measures include forest management approaches that avoid clear cutting; investments in new equipment and roads; and the purchase of forest insurance. Notably, most forest owners were also not convinced that taking measures against insects and fungi would be effective, even though they believed that such pests constitute one of the biggest risks to their forest in a changing climate (Table 6.3). Similarly, the majority of forest owners also did not believe that salvage cutting, or reforestation would be effective measures to deal with the perceived large and increasing risk from storms.

The results of the McNamer χ^2 test also shows that forest owners did not change their preferences for different forest management options over time. Even though the count and percentage of forest owners that favoured individual options changed between T-0, T-1 and T-2, none of these changes were statistically significant.

Influence of personal forest values on general views, perceptions and management preferences related to adaptation at T-0

This section addresses the second research question and presents results from the first questionnaire that forest owners answered before the start of the communications projects. Figure 6.1 shows the average importance of the 15 forest values grouped into the three different value dimensions (production and economic gain, environmental and climate action, and recreation and tradition). In brackets behind each value is the Kendall's tau correlation coefficient between the individual value and the index score of the relevant value

dimension. All forest values correlate at a statistically significant level with the index score of their respective value dimension.

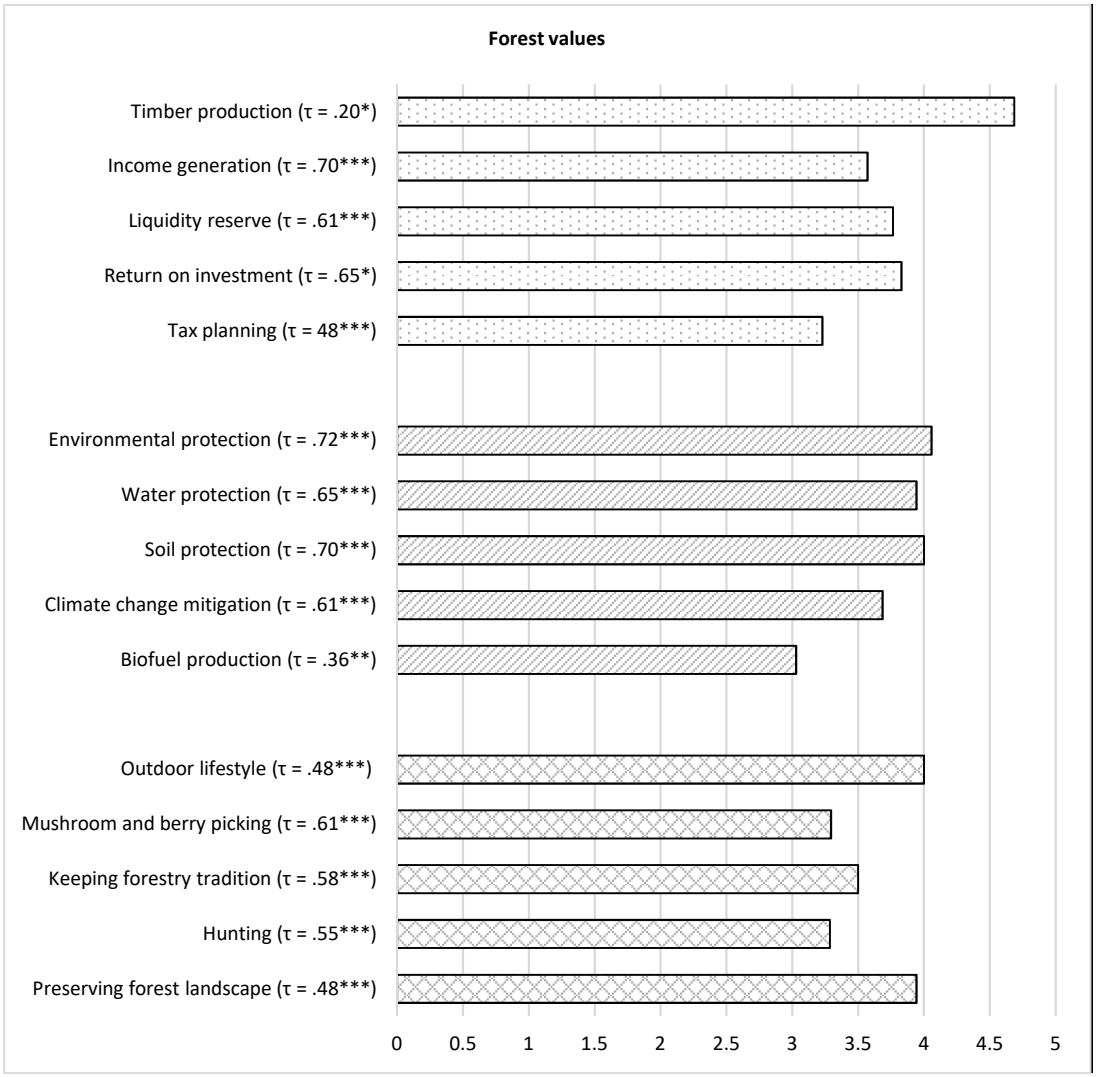

Figure 6.1: Forest owners' average importance of forest values

The results show that the most important objective for participating forest owners was timber production, followed by environmental protection, outdoor lifestyle, soil protection, preserving forest tradition and water protection. All of these had an average value of above or around four. Furthermore, the chart also shows that all values had a mean rating of above three, which indicates that forest owners on average considered all them as at least somewhat significant.

Table 6.4 shows the results of Kendall's τ correlation between general views on climate change, climate science and adaptation and the three forest value dimensions. The τ value used here can provide a measure of relative strength of correlation (Field et al. 2012). Unlike the Pearson correlation coefficient, however, τ values cannot be squared to reflect the proportion of shared variance between two correlated variables (Strahan 1982).

Results (from T-0) show that prior to the communication project, forest owners' concern about climate impacts, their perception of climate change risks both globally and for their own forest, and theirs belief about the credibility of climate science are positively correlated with their belief in environmental and climate action. The Kendall's τ test also indicates that there is a comparatively weaker correlation between production and economic values and forest owners' perception of local climate risks and their level of trust in climate science.

Table 6.5 presents the results of Kendall's τ correlation analysis of forest owners' perception of the seriousness of climate related risks today and in 50 years, and along the three value dimensions. The statistical analysis suggests that before the first focus group meeting, personal belief in environmental and climate action was significantly related to personal perception of the seriousness of current risks from storms, flooding, pests, and loss of biodiversity. Personal values related to recreation and tradition are also correlated with perceptions of the seriousness of current risks from storms and biodiversity loss. Furthermore, forest owners' assessments regarding how the risks of biodiversity loss will change in the coming five decades are significantly related with all three value dimensions.

Results of point-biserial correlation analysis between forest owners' preferences for forest management options to deal with climate change and the three value dimensions can be found in Table 6.6. The analysis shows that prior to the first focus group meeting none of the value dimensions are significantly related with any of the forest management options, except for the recreation and tradition dimension, which is correlated with salvage cutting and reforestation after storms

Table 6.4: Changes in the relation between forest owners' general views on climate change, climate science and adaptation and value dimensions[1]

Value dimension	**Production and economic gain**			**Environmental and climate action**			**Recreation and tradition**		
Statement	**T0**	**T1**	**T2**	**T0**	**T1**	**T2**	**T0**	**T1**	**T2**
I am very concerned about the global risk of climate change	τ = .19	τ = .27	τ = .01	τ = .35*	τ = .31*	τ = .36*	τ = .14	τ = .15	τ = .13
I am very concerned about the risk of climate change to my own forest	τ = .25	τ = .23	τ = -.08	τ = .34*	τ = .39**	τ = .27*	τ = .12	τ = .20	τ = .18
I consider the global risk of climate change to be very serious	τ = .23	τ = .16	τ = .11	τ = .59***	τ = .37**	τ = .32*	τ = .08	τ = .07	τ = .15
I consider the risk of climate change to my own forest to be very serious	τ = .28*	τ = .18	τ = -.05	τ = .48***	τ = .31*	τ = .30*	τ = .12	τ = .17	τ = .18
I consider the consequences of climate change for my forest to be negative rather than positive	τ = -.04	τ = -.13	τ = -.04	τ = -.13	τ = -.17	τ = -.19	τ = -.06	τ = .04	τ = .02
I believe that my own forest is resilient enough to cope with climate change	τ = -.03	τ = .09	τ = -.07	τ = -.00	τ = .02	τ = -.03	τ = -.04	τ = .15	τ = .25
I believe that I have enough knowledge to adapt my forest to climate change	τ = -.06	τ = .10	τ = -.03	τ = -.04	τ = -.12	τ = -.14	τ = -.07	τ = -.03	τ = -.05
I consider climate science to be trustworthy	τ = .27*	τ = .27*	τ = .20	τ = .39**	τ = .38**	τ = .39**	τ = .10	τ = .14	τ = .27*
I need to take climate change into greater consideration	τ = .22	τ = .33*	τ = -.04	τ = .25	τ = .32*	τ = .19	τ = .06	τ = .20	τ = .38**

[1] Only includes responses from forest owners that respond to all three questionnaires. N: 35

Significance codes: * p < .05, ** p < .01, *** p < .001

Table 6.5: Changes in the relation between forest owners' perceptions of climate-related risks and value dimensions[1]

Objective index	**Production and economic gain**			**Environmental and climate action**			**Recreation and tradition**		
Risks	**T0**	**T1**	**T2**	**T0**	**T1**	**T2**	**T0**	**T1**	**T2**
Storms – today	τ = .15	τ = .05	τ = -.06	τ = .47***	τ = .28*	τ = .11	τ = .26*	τ = .07	τ = .17
Storms – change in 50 years	τ = .07	τ = .18	τ = .00	τ = .19	τ = .44**	τ = .19	τ = -.00	τ = .23	τ = .07
Flooding – today	τ = -.02	τ = .04	τ = -.00	τ = .28*	τ = .22	τ = .36**	τ = .16	τ = .11	τ = .25
Flooding – change in 50 years	τ = -.05	τ = .04	τ = -.02	τ = .19	τ = .20	τ = .06	τ = .09	τ = -.01	τ = .05
Snow breakage – today	τ = -.10	τ = -.05	τ = .05	τ = .06	τ = -.16	τ = -.03	τ = -.07	τ = -.23	τ = -.04
Snow breakage – change in 50 years	τ = -.12	τ = -.02	τ = .07	τ = -.06	τ = .11	τ = .04	τ = -.05	τ = .15	τ = .25
Frost damage – today	τ = -.14	τ = .07	τ = .23	τ = .22	τ = .14	τ = .26	τ = .10	τ = .09	τ = .32*
Frost damage – change in 50 years	τ = -.05	τ = .12	τ = .06	τ = .20	τ = .29*	τ = .13	τ = .10	τ = .07	τ = .15
Drought and forest fire – today	τ = .04	τ = .10	τ = -.16	τ = .19	τ = .21	τ = -.01	τ = .19	τ = .01	τ = .15
Drought and forest fire – change in 50 years	τ = .00	τ = .02	τ = .07	τ = .06	τ = .24	τ = .15	τ = .06	τ = .09	τ = .03
Damage due to poorer ground conditions – today	τ = .15	τ = .23	τ = -.16	τ = .01	τ = .10	τ = .07	τ = .06	τ = .05	τ = .06
Damage due to poorer ground conditions – change in 50 years	τ = .23	τ = .20	τ = -.07	τ = -.02	τ = .09	τ = .05	τ = .05	τ = .09	τ = -.04
Pests such as bark beetles or root rot – today	τ = .22	τ = .16	τ = -.06	τ = .30*	τ = .29*	τ = .03	τ = .18	τ = .27*	τ = .21
Pests such as bark beetles or root rot – change in 50 years	τ = .14	τ = .19	τ = .09	τ = .09	τ = .19	τ = .03	τ = .23	τ = .13	τ = .08
Loss of biodiversity – today	τ = .16	τ = .26	τ = .02	τ = .36**	τ = .44***	τ = .14	τ = .40**	τ = .35*	τ = .26*
Loss of biodiversity – change in 50 years	τ = .30*	τ = .18	τ = -.04	τ = .38**	τ = .39**	τ = .03	τ = .31*	τ = .22	τ = .05

[1] Only includes responses from forest owners that respond to all three questionnaires. N: 35
Significance codes: * p < .05, ** p < .01, *** p < .001

Table 6:6 Relation between forest owners' preferences for forest management options to adapt to climate change and value dimensions[1]

Objective index	**Production and Economic gain**			**Environmental and climate action**			**Recreation and tradition**		
Risks	**T0**	**T1**	**T2**	**T0**	**T1**	**T2**	**T0**	**T1**	**T2**
Taking local conditions into greater consideration during planting or final felling	r_{pb}= -.07	r_{pb}= .09	r_{pb}= .26	r_{pb}= -.08	r_{pb}= -.08	r_{pb}= -01	r_{pb}= .02	r_{pb}= -.08	r_{pb}= .01
Shorter rotation period between planting and final felling	r_{pb}= .08	r_{pb}= .00	r_{pb}= -.33	r_{pb}= -.33	r_{pb}= -.02	r_{pb}= -.31	r_{pb}= -.25	r_{pb}= .07	r_{pb}= -.21
Increasing tree-species mixture and diversity	r_{pb}= .04	r_{pb}= -.14	r_{pb}= .05	r_{pb}= -.08	r_{pb}= .04	r_{pb}= .20	r_{pb}= .16	r_{pb}= .27	r_{pb}= .30
Harder pre-commercial thinning and cutting	r_{pb}= .06	r_{pb}= .07	r_{pb}= -.05	r_{pb}= .15	r_{pb}= -.08	r_{pb}= -.22	r_{pb}= .14	r_{pb}= .27	r_{pb}= .07
Forest management approaches that avoid clear cutting (e.g. continuous cover forest management)	r_{pb}= .22	r_{pb}= -.06	r_{pb}= .17	r_{pb}= .10	r_{pb}= .11	r_{pb}= .32	r_{pb}= -.25	r_{pb}= -.05	r_{pb}= .23
Taking measures against insects and fungi	r_{pb}= -.26	r_{pb}= -.01	r_{pb}= -.26	r_{pb}= -.23	r_{pb}= .05	r_{pb}= -.12	r_{pb}= -.08	r_{pb}= -.10	r_{pb}= -.10
Improvements to drainage ditches	r_{pb}= .15	r_{pb}= .20	r_{pb}= .13	r_{pb}= -.04	r_{pb}= .07	r_{pb}= .10	r_{pb}= .20	r_{pb}= -.16	r_{pb}= -.23
Salvage cutting and reforestation after storms	r_{pb}= .07	r_{pb}= -.11	r_{pb}= .17	r_{pb}= -.14	r_{pb}= -.06	r_{pb}= .15	r_{pb}= .40*	r_{pb}= -.42*	r_{pb}= -.41*
Purchase of insurance	r_{pb}= -.03	r_{pb}= .05	r_{pb}= -.09	r_{pb}= .05	r_{pb}= -.06	r_{pb}= -.42*	r_{pb}= .01	r_{pb}= .03	r_{pb}= .04
Investment into new equipment and roads	r_{pb}= .07	r_{pb}= .13	r_{pb}= .13	r_{pb}= .03	r_{pb}= -.07	r_{pb}= .03	r_{pb}= -.16	r_{pb}= -.09	r_{pb}= .10

[1] Only includes responses from forest owners that respond to all three questionnaires. N: 35

Significance codes: * p < .05, ** p < .01, *** p < .001

Effect of communication on the influence of personal forest values on general views, perceptions and management preferences related to adaptation

This section addresses the question over whether the communication project changed the influence of personal forest values on owners' views, perceptions and preferences regarding adaptation. To answer this question, we compare forest owners' responses before and after the communication project.

Table 6.4 shows results of the Kendall's τ correlation test between forest owners' general views on adaptation and value dimensions at T-0, T-1 and T-2. It shows that environmental and climate-related values have a consistent positive influence on forest owners' level of concern about the global risk of climate change and the degree of their trust in climate science. The analysis also indicates that the influence of environmental and climate-related values on forest owners' concerns and perceptions of risk for their own forest declined between T-0 and T-2. A similar decrease can also be observed in the relation between the same value dimension and perceptions of the global risks of climate change.

Results also indicate that between T-0 and T-2, the correlation between forest owners' levels of trust and their production and economic values was no longer evident; instead, trust became correlated with recreation and tradition values. Furthermore, none of the value dimensions are at any point correlated with forest owners' beliefs in their own knowledge to adapt their forest to climate change. The data also suggest that immediately after the climate change communication project ended, forest owners' value for production and economic gain, and environmental and climate action emerged as correlating positively with their perceived need to take adaptation into greater consideration. The same effect, however, cannot be observed at T-2. Instead at this point forest owners' perceived need for adaptation began to relate with their appreciation of recreation and tradition.

Result presented in Table 6.5 indicate that, both before the focus group meetings and immediately afterwards, personal appreciation for environmental and climate action has a relatively consistent effect on forest owners' perception of the seriousness of current risks from pests and current and future risks of biodiversity loss. However, the same effect is no longer observable at T-2. Similarly, the correlation between environmental and climate-related values and forest owners' perception of current storm risks is weaker at T-1 and absent at T-2. Results also suggest that immediately after the end of the climate change communication project, forest owners' value for environmental and climate action

correlated with their beliefs regarding the degree to which the risk from storms and frost will increase in the future. However, this change was fleeting, and did not surface at T-2.

Furthermore, the analysis also indicates that the correlation between forest owners' value for recreation and tradition and their perception of the seriousness of loss of biodiversity and storms either weakened or entirely disappeared after the focus group meetings. Results also show that production and economic values have no significant influence on how forest owners perceived of almost any current and future climate-related risks at any point before or after the climate change communication project.

Lastly, results in Appendix 13 also suggest that the general lack of correlation between value dimensions and forest owners' preferences for adaptation measures did not change after the climate change communication project.

6.4 Discussion

Forest owners in Sweden face impacts from climate change. Their appraisal of climate risks and their preferences for forest management options will play a key role in how the Swedish forest sector will adapt to climate change (Keskitalo et al. 2016). This study asked whether climate change communication could promote engagement with adaptation (Lorenzoni et al. 2007) by changing forest owners' views, perception preference related to adaptation. Our research followed insights from environmental psychology (Swim et al. 2009; Gifford et al. 2011). This line of the literature suggests that communication is a social process that can affect intrapsychic processes, including cognitive appraisal of climate change risks and adaptation options, affective responses, and motivated reasoning driven by personal values (Bradley and Reser, 2017; Grothmann and Patt, 2005; Swim et al., 2009). Based on results from a longitudinal study, we can infer how climate change communication can help forest owners in the understanding and planning stages of adaptation (Moser and Ekstrom 2010).

Unexpected emotional and cognitive response to climate change communication

Previous research suggests that climate change communication can increase individuals' concern and perception of the severity of climate change impacts (Akerlof et al. 2016). Results from this study, however, suggest a more complex relationship between communication and emotional and cognitive risk appraisals. Results showed that four-and-a-half years after the communication project, fewer forest owners felt concerned about the local consequences of climate change, and fewer participants thought that climate change

would pose serious risks for their forest. Over the same period, forest owners also became less convinced that climate-related risks would become more severe in the future.

This decline in forest owners appraisal of general and specific climate-related risks supports earlier research about the effect of bounded rationality on public perception of climate risks (Gifford et al. 2011), and about the tendency of individuals to respond to climate science by discounting uncertain future risks (Weber 2010). Furthermore, these results also highlight the possibility that increasing the personal relevance of climate change by highlighting proximal impacts may backfire (Brügger et al. 2015). An alternative explanation is that forest owners became less concerned about climate change and perceived their risks to be less serious because they concluded that risks were not as serious as they initially had expected, or because they become convinced that they had enough knowledge to adapt to climate change. This explanation would support the extensive literature on the importance of self-efficacy beliefs for behavioural change (Bandura 1977a) and individual adaptation to climate change (Niles et al. 2016). Furthermore, no major storms were recorded in Sweden between the end of the communication project and the third survey. The absence of such events also could have contributed to the diminished concerns about climate change that emerged.8

Little or no change in forest owners' general framing of climate change risks and preferences for forest management options

Forest owners in Sweden face the challenge of understanding how climate change will affect familiar risks such as storms and pests as well as emerging risks such as pests, biodiversity loss, drought and forest fires (Swedish Commission on Climate and Vulnerability 2007), and of choosing between reactive, active and proactive forest management options to adapt their forest (Jönsson et al. 2013).

Results from this study show that prior to the climate communication project, forest owners were most concerned about familiar risks from storms but also emerging risks from pests and damages from poorer ground conditions. At that time, they believed that these risks would become more serious in the coming five decades. Four-and-a-half years after the communication project, forest owners' perception of these three risks had not changed, but they considered these future risks as being less serious than they previously had thought. Notably, pests and damage due to poorer ground conditions are associated with storm risks. Bark beetle outbreaks have been observed after major storms in Sweden, and poorer ground

[8] https://www.smhi.se/kunskapsbanken/meteorologi/stormar-i-sverige-1.5770

conditions due to reduced or no ground frost can increase storm risks as tree roots have less anchorage in wet, unfrozen soil (Keskitalo et al. 2016). Thus, our results support earlier research that has shown that forest owners frame climate change in terms of risks associated with storms (Ulmanen et al. 2012; Vulturius and Gerger Swartling 2015; Andersson et al. 2018).

The study's outcomes also suggest that communication has had little influence on forest owners' appraisal of emerging risks or their preferences for forest management options to adapt to climate change. Both before and after the communication project, forest owners on average did not perceive biodiversity loss, drought or forest fires as serious risks today or in the future. No change was observed in owners' preference for forest management options to adapt to climate change. Forest owners were least convinced about non-conventional or capital-intensive measures, including forest management options, such as continuous-cover forest management, that avoid clear cutting, or investments into new equipment and roads. These results appear to support earlier research which has shown that forest owners do not follow expert advice (Uggla and Lidskog 2016), and that forest owners strongly resist changing risk perceptions (Eriksson 2014) and forest management strategies (Lidskog and Sjödin 2014).

Personal forest values influence owners' concerns and risk perceptions, but not their preferences for adaptation options

This study followed a values-based approach to adaptation (O'Brien and Wolf 2010) which presumes that personal values can be a barrier to individual engagement with adaptation (Wolf et al. 2013). Importantly, we focused on domain-specific values which have been shown to have greater influence on forest owners' risks perception and forest management than intrinsic values (Nordlund and Westin 2010; Eriksson 2014). In responding to the second research question, we assessed the influence of personal forest values prior to the communication project.

Results confirm previous studies which have shown that non-industrial forest owners in Sweden (Andersson and Gong 2010, Ingemarson et al. 2006; Berlin et al. 2006) and elsewhere (Wiersum et al. 2005) hold values that can be tied to three value dimensions including production and economic gain, environmental and climate action, and recreation and tradition using non-parametric correlation analysis. As discussed in section 6.2, due to the low number of cases it was no possible to conduct a more sophisticated analysis – like cluster

or factor analysis – to assess if individual values are independent of each other and if they form distinct value dimensions. However, research on forest owners in Sweden by Nordlund and Westin (2010) and on the Swedish public by Eriksson et al (2012) suggests that there is some correlation between forest values belonging to different forest value dimensions. Both studies also suggest that some of the variation in the preference for individual forest values and forest value dimensions found in this study can be explained by people's adherence to basic values (Schwartz 1992) of self-transcendence, self-enhancement, openness to change and conservation.

The analysis also suggests that forest owners that strongly value environmental and climate action are more concerned about the global and local consequences of climate change and have a higher level of trust in climate science. This supports earlier research which has shown that pro-environmental values are generally related to personal concerns and belief in climate change (Corner et al. 2014). In contrast to that same literature, however, results don´t suggest that forest owners with strong pro-environmental values have a stronger perceived need to take adaptive action.

Furthermore, results also show that the other two value dimensions have little or no influence on forest owners' general views related to adaptation and the perception of climate-related risks. Forest values related to production and economic gain showed only weak correlations with forest owners' general perception of climate change risks or their forests, and no correlation with any specific climate-related risks other than future biodiversity loss. Personal appreciation for recreation and tradition appear to have no influence on personal views on adaptation and are only correlated with perceptions about current risk from storms and current and future risks from biodiversity loss.

Findings also don´t show that forest values have a significant influence on forest owners' preferences for forest management measures to adapt to climate change.

Communication reduces the influence of values on risk perception

This study also examined the question of whether communication influences the degree to which personal forest values shape owners' views, perceptions and preferences regarding adaptation. This question is based on previous research by van der Linden and colleagues who have claimed that providing individuals with scientific information about climate change is sufficient to overcome values-based motivated reasoning on individual engagement with climate change (van der Linden et al. 2015, 2019).

Due to the absence of values that predisposed forest owners to be less concerned about climate change, to have lower risk perceptions, to distrust climate science, or perceive adaptation to be less urgent, this study cannot support the hypothesis that communication can overcome motivational barriers to individual engagement with adaptation (Akerlof et al. 2016; Kerr and Wilson 2018). Likewise, findings suggest that climate change communication did not affect the influence of environmental and climate-related values that predisposed forest owners to be more concerned about the global risk of climate change and their trust in climate science. This supports Corbett and Durfee (2004) who found that people who are predisposed to believe in climate change and who are concerned about its impacts because of their pro-environmental values are unlikely to change their views in response to new information that highlights the uncertainty of climate science.

However, results also show that after the communication project, pro-environmental values had less of an influence on forest owners' appraisal of the risk of climate change globally and for their own forest, as well as of several specific climate-related risks including current risk from storms. This would suggest that communication reduces the influence of values that predispose them to have higher risk perception. Given that previous research has shown that personal assessment of climate change risk is one of the strongest predictors of personal intentions to take adaptive measures (Vulturius et al. 2018), these result appear to indicate that communication can reduce personal engagement with adaptation amongst those that are predisposed to be more engaged. One possible reason for this could be that forest owners with strong pro-environmental values concluded that they weren´t as threatened by climate change as they thought they were.

Communication in the context of the Swedish forest sector

Our results can also be seen in the context of the Swedish forest sector. Andersson et al. (2018) found that forest owners are beginning to challenge the Swedish industry´s production-orientated paradigm, its tendency to downplay the risks from storms and climate change, and its adherence to a business-as-usual approach that does not compromise short-term economic gains to adapt to climate change. Our results appear to confirm their findings that forest owners generally follow a more diverse set of values and worry about the effect of climate change on storm risks.

However, we also find that despite climate change communication, forest owners' concern and appraisal of current and future climate change declined over the period of the study.

This could suggest that forest owners adhered to the forest industry's short-term focus and approach to climate change (Andersson et al. 2018). In contrast to the findings in previous research (Nordlund and Westin 2010), our work shows no evidence that personal forest values influence forest owners' preferences for forest management options to adapt to climate change. Instead, it appears that forest owners generally follow the business-as-usual approach taken by the Swedish forest industry (Andersson and Keskitalo 2018). Overall, these results could imply that communication has been unable to counter the influence of the dominant norms and rationales of the Swedish forestry industry on forest owners' views on climate risks and adaptation.

Limitations of the study and implications for future research

This study has several limitations that should be considered when interpreting its results. Notably, the study's participants cannot be considered representative of private forest owners in Sweden. Compared to a random sample of forest owners in Sweden, the participating group included an overrepresentation of female forest owners, forest owners who depended on forestry income, and owners with forestry certification credentials (Vulturius et al. 2018). These differences can be explained by the study´s intention to sample a diverse set of forest owners from areas that face different climatic conditions. We argue that because a heterogeneous group of forest owners participated in the study, a greater diversity of forest values and attitudes about climate change adaptation was captured – an approach that is like that advanced in Eriksson (2014).

The study faces the challenge of attributing changes in personal views, perceptions and preferences related to adaptation to climate change communication. In her study on long-term changes in individual engagement with climate change, Howell (2014) argues that it is difficult to isolate the impact of a single intervention when individuals are influenced by many other sources of information about climate change. The problem of attribution is further complicated by the study's relatively small number of participants (45), which limits the statistical methods to descriptive tests of differences and bivariate correlation analysis. We suggest that future studies should aim for a larger number of participants to use multivariate analysis and inferential statistics to better understand the underlying reasons behind individual cognitive, emotion and behavioural responses to climate change communication (Capstick et al. 2015). Such studies could incorporate analysis of the potential influence of the media (Fernández-Llamazares et al. 2015), sources of expert and local knowledge

(Bohensky et al. 2016), political (dis)incentives for adaptation (Eriksson 2018), and personal experiences with extreme events (Demski et al. 2017). We also see great value in combining quantitative data to analyse the magnitude of the effect of climate change and qualitative data to analyse the why and how of the effect (Gifford et al. 2011).

The use of Likert scale in this study is another limitation. As described in section 6.2, there is an ongoing discussion in the scientific literature if data from a Likert scale response format can be used in statistical tests that require interval data (Lindell and Kruschke 2018). To address this issue, we used non-parametric tests in this study. Future studies should follow the advice by Carifio and Perla (2007) to move away from an item-by-item analysis of Likert scale data and instead design Likert scales that measure a theoretical concept using multiple response items. Insights from this study show how this can be done to measure the concept of individual engagement with adaptation and the different dimensions of forest values.

Future studies with a larger number of cases should use cluster analysis (Blanco et al. 2017b) or factor analysis (Hine et al. 2015) to further examine the questions if there are groups of people with distinct values that differ in their level of engagement with adaptation. Like Lorenzoni and Hulme's (2009) study of public trust in climate science, this research could develop a typology which would help in targeting and tailoring climate change communication to promote individual engagement with adaptation. This research should also consider research by Blanco et al (2015) that showed that values are only one of three characteristics relevant to create typologies of forest owners in the developed world – the other two characteristics being preferences for management practices and socio-economic attributes.

Furthermore, future research should also go one step further and investigate how different forms of climate communication can change actual behaviour. While this type of research would face an even greater potential for attribution error (Jones and Harris 1967), it promises greater insights into how climate change communication can overcome the gap between concern and adaptation action (Bradley and Reser 2017). This research should also assess how climate change communication aiming to change the antecedents of adaptative behaviour can be combined with structural changes such as regulations and rewards that change the circumstances under which behaviourally relevant decision are being made (Gifford et al. 2011).

Another interesting future research question is whether climate change communication can be more successful in affecting domain-specific values, such as personal forest values that impede individual engagement with adaptation than more deeply rooted worldviews and political ideology (Kerr and Wilson 2018). This research could offer valuable insights for the current debate about the limits of communication to overcome political polarization about climate change (Kahan and Carpenter 2017; van der Linden et al. 2017). It could also help communication practitioners in aligning their framing and messaging to target audiences' behaviour-specific attitudes and motivations (Gifford et al. 2011) and improve support for policy interventions (Nilsson et al. 2016).

Conclusion

In conclusion, findings of this study suggest that climate change communication had both expected and unexpected influences on forest owners' cognitive and emotional engagement with adaptation. The results show that communication leads forest owners to become more confident in their personal knowledge to adapt to climate change; results also indicate that such communication leads owners to become less concerned, and to take the risks of climate change for their own forests less seriously. Findings also indicate that communication did not change forest owners' storm-centred framing of climate change or their business-as-usual approach to forest management. Having pro-environmental values appears to increase concern and perception of climate change risks. Nevertheless, preferences for forest management practices appear independent of personal forest values. More long-term research is needed on the effect of communication on basic and domain-specific values and the combination of communication with structural changes in regulations and policies.

Chapter 7: Discussion and conclusion

The final chapter of the thesis first summarises the results, key findings and synthesis (7.1) before discussing its limitations (7.2). The final section presents the overall conclusions of the thesis (7.3) and makes recommendations for future research (7.4)

7.1 Summary of the research chapters, key findings and synthesis

Chapter 3: The relative importance of subjective and structural factors to individual adaptation to climate change by forest owners in Sweden

Chapter 3 (Paper 1) of the thesis addresses the first aim of the thesis: to better understand the effects of structural and intrapsychic factors on the personal sense of the need and intention to adapt. Determinants of adaptive capacity and intrapsychic factors were chosen to assess two different approaches to explaining individual engagement with adaptation: the determinants-based approach (Brooks et al. 2005) and the psychological approach (Grothmann and Patt 2005; Swim et al. 2009). To test these two approaches, the chapter analysed responses to a survey of randomly selected forest owners in Sweden. To examine the relevance of the determinants-based approach, the survey contained questions about forest owners' objective adaptative capacity and exposure to climate change risk measured in terms of their income, level of education, size of forest property and dependency on income from forestry. To test the psychological approach, the survey asked about intrapsychic conditions – personal assessment of climate change risk, concern about the global and local consequences of climate change, self-efficacy beliefs, trust in climate science – as well as experiential factors such as personal experience of extreme events, attribution of experience of extreme events to climate change and experience of risk mitigation. Furthermore, the survey included questions about intrapsychic responses related to climate change on the personal sense of need to adapt and intention to take risk-mitigating measurers to address climate change in the next five years. Taken together, the chapter is based on an adjusted version of Grothmann and Patt's (2005) Model of Proactive Adaptation to Climate Change. Ordinal and binary logistic regression was used to analyse forest owners' responses to the survey.

Overall, the results found that only a minority of forest owners had a greater perceived need to take climate change into consideration, but almost 40 per cent of them stated that they intended to take risk-mitigating measures to address climate change in the near future. The

statistical analysis also revealed that intrapsychic conditions were the only significant predictors of perceived need to adapt and intention to adapt. Personal assessment of climate change risk and belief in a connection between personal experience of extreme events and climate change were shown to have a statistically significant influence on both measures of intrapsychic response related to adaptation. Furthermore, the analysis indicated that forest owners with a higher level of trust in climate science had a stronger sense that they needed take climate change into greater consideration; and that owners that had experience of risk-mitigating measures and believed that they had enough knowledge to adapt their forest were more likely to intend to take adaptive measures in the near future. Importantly, the results did not find evidence that determinants of adaptive capacity, experience of extreme events or concern about the local or global consequences of climate change had any significant effect on forest owners' intrapsychic responses in relation to adaption.

Taken together, the most important finding of Chapter 3 was that intrapsychic conditions – personal appraisal of climate change risk, trust in climate science and belief in personal knowledge – were shown to have a significant influence on forest owners perceived needs and intentions regarding adaptation. This result supports the general approach of this thesis. The question "Can climate change communication promote individual engagement with adaptation?" can be answered by examining the influence of communication on intrapsychic conditions and intrapsychic responses related to adaptation.

Chapter 4: Does climate change communication matter for individual engagement with adaptation? Insights from forest owners in Sweden

Chapter 4 (Paper 2) addressed the second aim of the thesis: to assess the effect of transmission-orientated climate change communication on individual engagement. Proceeding from the findings of Chapter 3, this chapter only considers intrapsychic conditions and intrapsychic responses related to adaptation. Climate change communication is considered part of the societal discourse on climate change that affects the drivers and responses of individual engagement with adaptation (Moser 2014). To assess the influence of communication on individual engagement with adaptation, the chapter used a survey of two groups of forest owners: a group made up of participants in two climate communication projects organised by the Swedish Forest Agency (SFA) and a group consisting of a random

sample of forest owners.[9] The communication projects led by the SFA took a transmission-oriented approach to communication by disseminating tailored information about climate risks and adaptation measures to forest owners at evening meetings, courses or individual consultations led by experts from the SFA (Nordström 2014). To analyse the data, the chapter used comparative test statistics, regression analysis and mediation analysis.

The comparison found statistically significant but only small differences between the two groups in terms of intrapsychic factors for individual engagement with adaptation. On average, the forest owners who participated in communication projects run by the SFA perceived the risk of climate change to their forest to be more severe than their peers in the other group, had a stronger belief in their self-efficacy, were more concerned, were more likely to attribute their experience of extreme events to climate change and had a higher level of trust in climate science. Similarly, forest owners who took part in climate change communication also had a greater perceived need to adapt to climate change and more of them intended to take adaptive measures in the near future. The results of the regression analysis also suggested that communication on its own had only a small, albeit significant, direct effect on forest owners' perceived needs and intentions to adapt to climate change. As in Chapter 3, the regression analysis found that those forest owners who believed that they were knowledgeable about the issue were also more likely to have an intention to take adaptive action soon. Furthermore, the mediation analysis suggested that communication had some indirect effect on intrapsychic responses to adaptation by affecting forest owners' risk assessments, levels of concern about climate change impacts and trust in climate science, as well as the degree to which they attributed their experience of extreme events to climate change. In addition, the study found that experience of extreme events is associated with a positive effect on personal intentions to take adaptive action regardless of personal belief that these experiences were caused by climate change.

From the point of view of understanding whether – and if so how – climate change communication can promote individual engagement with adaptation, this chapter made two key findings. First, the results appear to suggest that climate change communication based on a transmission-orientated approach has only a small direct and indirect effect on

[9] This is the same group that was analysed in Chapter 3. Note that the total number of randomly selected forest owners was slightly higher in Chapter 4 (909) than in Chapter 3 (836). This is because data from Chapter 3 was also used in Blanco et al. (2017b) for multidisciplinary research on forest owners and agent-based modelling, which limited the number of valid responses.

intrapsychic conditions and intrapsychic responses related to adaptation (cp. Pearce et al. 2015). Second, the chapter concluded that longitudinal (Howell, 2014) and qualitative research is needed to gain a better understanding of any potential intrapsychic and behavioural outcomes from climate change communication.

Chapter 5: Successes and shortcomings of climate communication: insights from a longitudinal analysis of Swedish Forest owners

Chapter 5 (Paper 3) addresses the third aim of the thesis: to examine the short- and long-term effects of deliberation-orientated climate change communication on individual engagement with adaptation. This chapter and Chapter 6 are based on a climate change communication project that was designed as a science-based stakeholder dialogue (Welp et al. 2006a). This communication project consisted of three different focus group meetings and one workshop, which involved 45 forest owners in Sweden as well as a climate modeller and forest management researchers. The meetings were more structured than other types of focus group, and involved scientific presentations about future climate change impacts and forest management options to facilitate knowledge exchange between participants (cp. Kasemir et al. 2003). To address the methodological shortcomings of the cross-sectional quantitative surveys used in Chapter 4, this chapter was based on a panel survey of forest owners who participated in the communication project. Surveys were conducted before the project started, immediately after the end of the final group meeting and four-and-a-half years after the first meeting. Furthermore, to overcome the limitations of the quantitative approach taken in Chapters 3 and 4, this chapter also drew on interviews undertaken between the final focus group meeting and the workshop. Another difference between this chapter and the first two papers is that it not only assesses changes in intrapsychic conditions and responses, but also reports on behavioural change related to climate change adaptation.

The findings from the interviews showed that forest owners appreciated the participatory approach taken by the communication project and the opportunity to ask scientists about their work and to discuss their findings with them and other forest owners. The findings from the qualitative and quantitative data suggest that, on average, forest owners had developed greater confidence in climate science, but also that communication has limited potential to change the opinions of individuals who strongly distrust climate science. The interviews also revealed that forest owners base their forest management decisions on their personal judgement and a wide range of sources of information. Data from the interviews and the

panel survey showed that after participating in the communication project, forest owners had greater confidence in their own knowledge of how to adapt their forests to climate change. The quantitative and qualitative data also indicated that the scientific knowledge presented during the focus group meetings had helped forest owners connect personal experience of changing weather, climate and forest conditions to climate change. However, the research also identified several unexpected results. The quantitative data analysis showed that four-and-half-years after the first focus group meeting, forest owners had become less concerned, on average, about the consequences of climate change for their forest and fewer thought that it would pose serious risks to their forest. In addition, the panel data did not demonstrate that forest owners had made any considerable changes to the way they managed their forests.

The most significant finding in this chapter is that communicating scientific knowledge about climate change is a complex socio-cognitive process that depends on its perceived credibility (Asplund, 2018), legitimacy and relevance (Vulturius and Gerger Swartling, 2015), as well as people's heuristics and experiences of climate-related risk and risk-mitigating behaviour. Furthermore, the results also showed that deliberation-orientated communication can help audiences relate their experience of extreme events to climate change (Marx et al. 2007).

Chapter 6: The influence of climate change communication and personal forest values on engagement with adaptation among forest owners in Sweden

Lastly, Chapter 6 (Paper 4) addresses the fourth aim of the thesis and assesses how climate change communication and domain-specific values influence personal engagement with adaptation in the short and long term. It is based on the same transmission-orientated communication project as Chapter 5. The chapter complements the previous papers by considering the influence of values and motivated reasoning on personal engagement with climate change. Based on previous research on forest owners in Sweden (Nordlund and Westin 2010), the chapter focuses on the influence of domain-specific values that reflect why people value forests. The chapter also goes beyond the scope of Chapter 5 by examining how communication and forest-specific values influence forest owners' assessment of specific climate-related risks and preferences for forest management options for adapting to climate change. The chapter draws on the same panel survey of forest owners used in Chapter 5.

The results indicate that four-and-a-half years after the communication project began, there was little or no change in how forest owners appraised the potential impacts of current and

future climate-related risks. The findings also indicate that most forest owners continued to be most concerned about familiar risks related to windfall. The analysis did not show any significant change in forest owners' preferences for forest management options that address climate change. In addition, the results revealed that forest owners with environmental values were, on average, more concerned about climate change, considered climate change risk to be more severe and had stronger trust in climate science. Values linked to income generation or recreation were not found to have a considerable influence on forest owners' level of engagement with adaptation. Nor did the statistical analysis provide any evidence that forest values had an influence on owners' assessment of specific risks or preference for forest management options. Furthermore, the chapter showed that communication had little or no effect on the correlation between personal forest values and owners' general views and preferences related to adaptation. However, the survey responses showed a general decline in the correlation between risk perceptions and personal appreciation of pro-environmental values after the communication project had taken place.

The key finding of this chapter is that communication appears to have had little effect on shifting forest owners' framing of climate change in terms of storm and windfall risk or changing their minds about preferred forest management options for adapting to climate change. This suggests that many forest owners struggle to move away from the business-as-usual approach to climate change and adaptation taken by the Swedish forest industry (Andersson and Keskitalo 2018). Furthermore, the paper indicated that forest-specific values had little influence on personal engagement with adaptation.

Synthesis: Climate change communication to promote individual engagement with adaption in the context of the Swedish forest industry

This thesis followed the actor-centred approach to research on adaptation (Klein and Juhola 2014; Eisenack et al. 2014) and proceeded from the assumption that how individuals respond to climate change is shaped by psychological factors (Swim et al. 2009; Wolf and Moser 2011). To understand whether, and if so how, communication can change personal perceptions, that is cognitive, affective and evaluative internal representations (Whitmarsh and Capstick 2018), as well as intentions and behaviour related to adaptation, the thesis drew inspiration from several approaches to intrapsychic and behavioural change: the theory of planned behaviour (Ajzen 1991), the model of private proactive adaptation to climate change

(Grothmann and Patt 2005) and the model of individual adaption to climate change by the American Psychological Association (APA) (Swim et al. 2009).

Figure 7.1 is a representative model of climate change communication to promote individual engagement with adaptation among non-industrial private forest owners in Sweden. The model represents the synthesis of this thesis and builds upon the conceptual and analytical model presented in Figure 3.1. It combines insights from research conducted as part of this thesis (Chapters 3–6), from research carried out in connection with this thesis (Blanco et al. 2017a, b; André et al. 2017) and from the literature on climate change communication and the role of non-industrial forest owners in forest management and adaptation in Sweden that has been published since research for this thesis started in 2013 (Andersson and Keskitalo 2018; Andersson et al., 2018; Lindahl et al., 2017; Lidskog and Sjödin 2014). Additions to the original model in Figure 3.1 are highlighted with a dashed outline in Figure 7.1. As described below, additions include cognitive biases and heuristics, motivational factors, adaptive or maladaptive behavioural responses, collective adaptive capacity and action, institutional and socio-economic moderators and of course climate change communication. The arrows that are included in figure indicate relationships between different elements of the model. These relationships are numbered and described in detail below. Please note that the numbering does not rank the relationships in order of importance or strength.

The first building block of the model presented in Figure 7.1 consists of the three components of individual engagement with climate change: intrapsychic conditions, intrapsychic responses and behavioural responses. Intrapsychic conditions that had already been included in Figure 3.1 are personal appraisal of climate risks and adaptation options, affective responses to climate change, experiences with extreme events and beliefs about the trustworthiness of climate science and about the causal relationship between personal experiences with extreme events. A recently published meta-review suggests that at least some these conditions – risk perception, personal experience with extreme events and perceived self-efficacy and knowledgeability – can explain individual engagement with climate change adaptation irrespective of context (van Valkengoed and Steg 2019). It should be noted that it was not the objective of this thesis to assess the interdependencies of these intrapsychic conditions.

Based on insights from Chapter 6, motivational factors – domain-specific forest values and basic beliefs – were added to the model. Results of Chapter 6 suggest that domain-specific

forest values – in particular pro-environmental values – can influence personal appraisal of climate change risks, self-efficacy beliefs, affective responses, trust in climate science or the attribution of personal experience to climate change. Given the ongoing scientific discussion about the effect of motivated reasoning on public opinion about climate change (Kahan and Carpenter 2017), including adaptation (Akerlof et al. 2016), basic values related to place attachment (Scannell and Gifford 2013), trust in climate science (Leiserowitz et al. 2013), social identity (Wolf et al. 2013) and responsibility for adaptation (Howell et al. 2016) are also included in the model even though they were not part of this thesis. Based on the findings in Chapter 5, cognitive biases and heuristics affecting forest owners' assessment of climate change risk and adaptation options were also added to the model. As discussed in that Chapter 5, the observed decline in forest owners' appraisal of and concern about climate change risk may have been caused by the lack of extreme events between 2014 and 2018, indicating recency bias (cp. Weber 2010).

The model also recognises that determinants of objective adaptive capacity (Brooks et al., 2005), as they apply to forest owners (Lindner et al. 2010), influence intrapsychic conditions ①. As described in Chapter 3, the model assumes that personal exposure to climate change risks measured in terms of size of forest property and dependency on income from forestry influences how forest owners assess climate change risk and act to address it (Blennow et al. 2012). It is also considering it likely that forest owners who own large forest property and are more economically dependent on it will be more experienced at forest management and more likely to have suffered from extreme events. Research also suggests that forest ownership properties in connection with forest management experience and heuristics influence forest owners' attitudes to risk (Andersson 2012) and ability to make rational decisions when faced with uncertainty (Andersson and Gong 2010). There is also evidence in the literature that at least among forest owners in Sweden, level of education predicts personal assessment of climate change risk regardless of personal values (Blennow et al. 2016). Thus, the factors behind forest owners' objective adaptive capacity are expected to directly and indirectly influence personal intentions and actions related to adaptation.

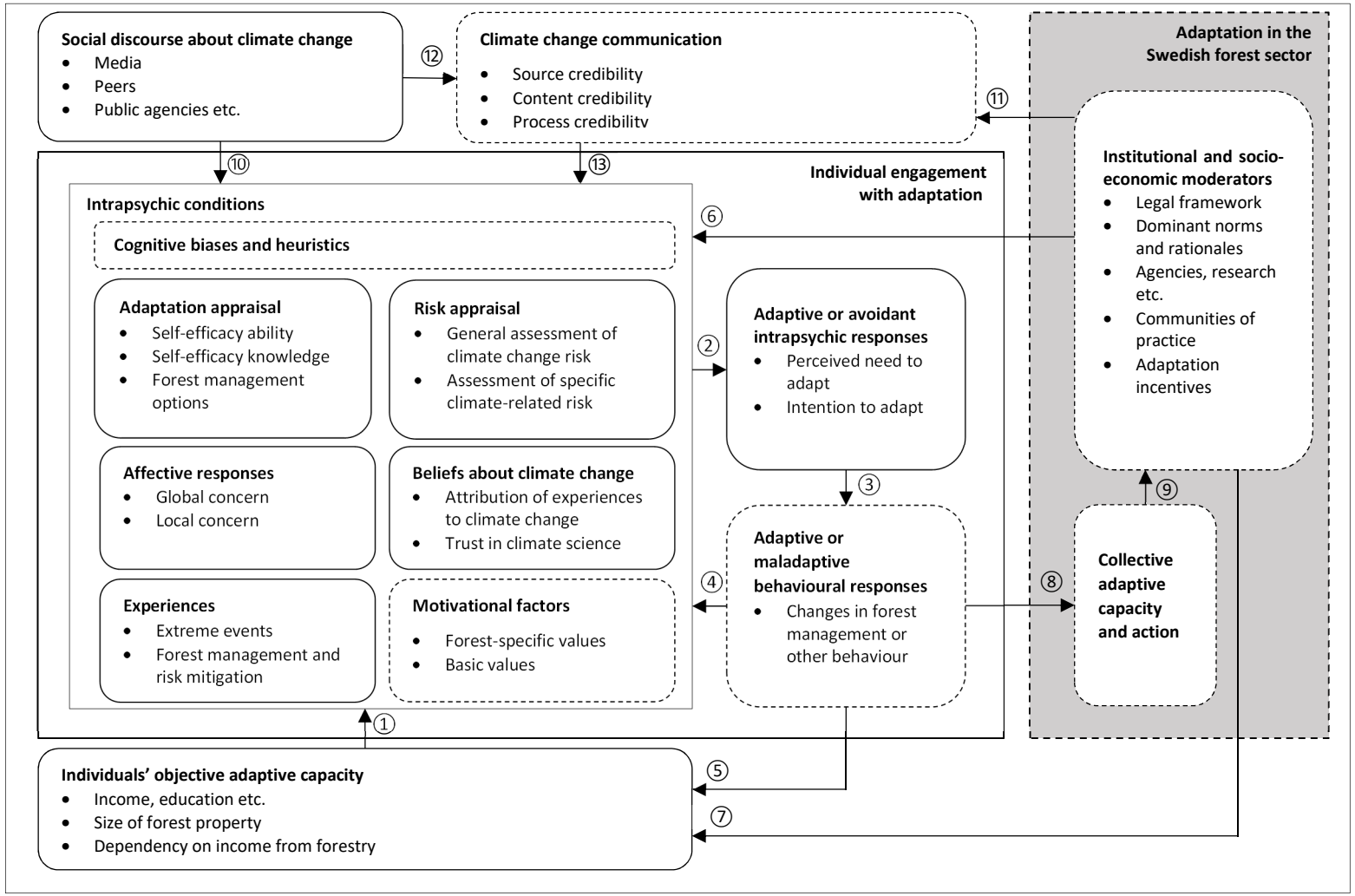

Figure 7.1: Model of climate change communication to promote individual engagement with adaptation among non-industrial private forest owners in Sweden

Based on the literature discussed in Chapter 2 and the empirical evidence presented in Chapters 3–6, the model in Figure 7.1 assumes that intrapsychic conditions can lead to individual responses to climate change. The model follows the theoretical literature discussed in Chapter 2 by separating intrapsychic responses from behavioural responses (Ajzen 1991). As suggested by the APA (Swim et al. 2009) and Grothmann and Patt (2005), the model proposes that intrapsychic conditions lead to intrapsychic responses to adaptation that can be adaptive or avoidant ②. Intrapsychic response can in turn lead to adaptive (Smit and Wandel 2006b) or maladaptive (Barnett and O'Neill 2010) behavioural responses ③. In terms of intrapsychic responses, the results in Chapter 5 show that after the end of focus group discussions, some forest owners considered taking measures to adapt to climate change. However, the results in Chapter 6 and the literature (Lidskog and Sjödin 2014) suggest that most forest owners are not considering proactive, non-conventional forest management options due, among other things, to perceived uncertainty about future climate risks and adaptation benefits. Similarly, as Chapter 5 indicates, forest owners can also respond to climate change by discounting future risk (Weber 2010).

The model also assumes that behavioural responses to climate change can influence future individual engagement with climate change ④. The results from Chapter 5 and Chapter 6 suggest that forest owners' preferences for forest management measures to adapt to climate change may be influenced by personal experience of those measures, meaning that there is feedback between experiences of risk mitigation and adaptation appraisal (Bubeck et al. 2012). Similarly, Tomlinson and Rhiney (2018) found that personal experiences with effective measures against pest outbreaks and landslides led to a higher level of perceived self-efficacy among Jamaican farmers. Conversely, taking maladaptive measures – like planting tree species that are prone to wind damage (Valinger and Fridman 2014) – can adversely affect the capacity of individuals to adapt to climate change ⑤.

In addition to Figure 3.1, the model in Figure 7.1 also includes institutional and socio-economic moderators that influence how the Swedish forest sector adapts to climate change. These moderators are assumed to play a decisive role in shaping individual and collective engagement with climate change adaptation (Swim et al. 2009). This reflects research on adaptive natural resource management and governance, which suggests that individual adaptation is embedded in a complex and multi-layered socio-ecological system or systems (Folke et al. 2005; May and Plummer 2011). As highlighted by Ostrom (2005), it is necessary

to understand the institutional arrangements that govern socio-ecological systems in order to promote sustainable resource management. Institutions in this model refer to social and decision-guiding norms that are self-enforcing and that exert pressure on individuals to conform to written and unwritten rules, heuristics or rationales (Dequech 2009). Institutions also include formal or informal organisations such as governmental agencies, research organisations, non-governmental organisations or communities of practice that impose or challenge institutional norms (Gibson et al. 2000). Furthermore, institutions, together with socio-economic conditions, define the adaptive capacity of the Swedish forest sector and its potential for collective action (Lindner et al. 2010).

As suggested in Chapter 6, institutional and socio-economic moderators influence intrapsychic conditions by shaping forest owners' appraisal of climate change risks and adaptation options ⑥. This may help to explain forest owners' lack of engagement with adaptation. As Andersson and Keskitalo (2018) have pointed out, business-as-usual remains the logical choice for the forest industry given its focus on short-term economic gain and global competitiveness. Even though forest owners have more diverse values and objectives for their forest management (Berlin et al., 2006, Chapter 6), they are influenced by the norms and rationale of the forest industry, including its framing and approach to climate change risk and adaptation (Andersson et al. 2018). Aside from economic pressure, forest owners are also limited in how they can manage their forest by legislation on environmental protection, species selection or protection of special interests such as reindeer husbandry (Lindahl et al. 2017). Legislation can also include incentives for adaptation action such as subsidies for tree species diversification (Lidskog and Sjödin 2014). Furthermore, individual owners are influenced in their forest management decisions and their views and actions on climate change by communities of practice such as forest owner associations, other forest owners or research organisations (André et al. 2017). Thus, by influencing forest owners' intrapsychic conditions to climate change, institutional and socio-economic moderators also indirectly influence intrapsychic responses and behavioural responses. In addition, moderators can also have direct impact on forest owners' objective adaptive capacity by e.g. setting incentives that can increase forest owners' dependency on income from forestry ⑦.

Importantly, the model also acknowledges that how individual forest owners respond to climate change will affect the adaptive capacity and actions of other stakeholders in the forest sector ⑧. Based on the data used in Chapter 3, Blanco et al. (2017b) found that forest

management with multiple objectives enhances the adaptive capacity of the Swedish forest sector because it maximises resilience and the provision of ecosystem services (Blanco et al., 2017). As others have pointed out (Pelling et al. 2008; Diduck 2010), the adaptive capacity of a complex socio-ecological system also depends on the possibility that individuals, communities and organisations might learn from each other within and across different organisational and governance levels. Experience with voluntary forest certification standards in Sweden also seems to suggest that individual and collective action can influence sector-wide institutions and socio-economic moderators (Elliott and Schlaepfer 2001), including norms on forest management objectives and practices (Schlyter et al. 2009) ⑨.

The model in Figure 7.1 also assumes that the social discourse on climate change influences individual engagement with adaptation ⑩. As outlined in Chapter 2, how individuals appraise climate change risks and adaptation options is influenced by what they here from the media, their peers or public agencies (Grothmann and Patt 2005). Thus, the social discourse about climate change ranges from political debates to casual conversations with family members or friends (Moser 2010). Research based on data from this thesis has shown that forest owners in Sweden draw from a variety of expert and non-expert sources of information about climate change – and that media is the most common source (André et al. 2017). Results from Chapter 5 as well as earlier research on forest owners in Sweden (Vulturius and Swartling 2015) also suggest that many forest owners discuss information about climate change with other forest owners or family members. By responding to the social discourse about climate change – by changing behaviour or talking about it with their peers – forest owners engage in the social amplification of climate change risks (Kasperson et al. 1988).

The question remains how climate change communication fits into the model. Like in Chapter 2, the model defines climate change communication as intentional efforts aimed at promoting individual and collective awareness, understanding and action on the issue (Markowitz and Guckian 2018) through persuasion and deliberation (Johnson 2012). The model situates climate change communication at the intersection between the process of adaptation of the Swedish forest sector ⑪ and the wider social discourse about climate change ⑫. As described in Chapter 4, the SFA's communication projects were organised in response to recommendations made by the Swedish Commission on Climate and

Vulnerability (2007). Similarly, the communication project covered in Chapter 5 and Chapter 6 was developed based on forest research and the Commission's recommendations.[10]

In line with the theoretical assumptions described in Chapter 2 and the empirical findings presented in Chapters 4–6, and summarised in the previous section, the model proposes that climate change communication can directly influence the intrapsychic conditions behind individual engagement with climate change ⑬. The model highlights the importance of the perceived credibility of the source, content and process of communication (Peters et al. 1997; Asplund 2018). As has been pointed out in the literature, these issues are crucial for translating scientific information into actionable knowledge and action (Cash et al. 2003; Meinke et al. 2006). The findings of this thesis help to better understand how communication affects people's perceptions of the credibility of climate science. First, Chapter 3 and Chapter 4 show that trust in climate science is a significant, albeit small, predictor of perceived need and intention to adapt (van Valkengoed and Steg 2019). Second, Chapters 4–6 suggest that communication had a positive short- and longer-term effect on the perceived credibility of climate science. Chapter 5 also indicates that the observed increase in trust in climate science was at least partly due to the deliberation-orientated approach to communication (Moser 2016). Furthermore, the results in Chapter 5 support the argument made in the literature that the credibility of scientific knowledge relies on its empirical credibility – that is, how well it resonates with personal knowledge, experience and objectives (Vulturius and Gerger Swartling 2015; Asplund 2018). Thus, the argument can be made that climate change communication that recognises non-expert knowledge (Wibeck 2013) and that facilitates knowledge co-creation and ownership (Rapley et al. 2014) is more likely to be perceived as credible and better at promoting individual and collective engagement with climate change adaptation.

Even though the model presented in Figure 7.1 focuses on the Swedish forest sector, it can inform research about climate change communication in other contexts. Studies on forest owners, farmers and other land use managers in other countries (Akerlof et al., 2016; Arunrat et al., 2017; Blennow, 2012) support the model's underpinning assumptions that communication promotes engagement with climate change by influencing the intrapsychic antecedents of behaviour; and that personal views, intentions and behaviour are shaped by institutions and socio-economic conditions. Thus, the model can be considered transferable.

[10] The Mistra-SWECIA project was launched in 2007 in response to the Swedish Commission on Climate and Vulnerability.

7.2 Limitations of the thesis

Many of the limitations of the thesis arise from its use of quantitative data to measure personal perceptions, beliefs and values related to climate change. As discussed in Chapter 4, quantitative data is poor at capturing the complex process of how people make sense of their personal and mediated experience and knowledge about climate change and how they respond to it (Mertens 2015). To address this shortcoming, Chapter 5 drew inspiration from mixed-methods research (Johnson and Onwuegbuzie 2004) and used quantitative and qualitative data. However, Chapter 5, like the rest of the thesis, is still restricted to the deductive approach to social science, which tests research hypotheses rather than undertaking grounded theory building (Shah and Corley 2006). The deductive approach is most commonly used in research that tests the importance and effect of different psychological factors on individual attitudes and actions related to climate change (Reynaud et al. 2013).

Furthermore, when interpreting results from quantitative data analysis it is important to keep in mind that correlation does not necessarily imply causation (Bryman 2012). The words "effect" and "effectiveness" are used throughout this thesis to describe the statistical relationship between two or more variables (Cohen 1992), for example that communication influences personal intentions to adapt to climate change. Cross-sectional data is particularly poor at establishing causality in terms of temporal order of cause and effect (Davis 1985). Chapter 4 attempted to address this issue by making the argument that covariance can help to infer knowledge about the dependency of different variables (Rindfleisch et al. 2008). To capture the importance of covariance methodologically, the chapter used regression analysis. This has been used before on cross-sectional data to learn about the effect of public health (Adebajo et al. 2015) and marketing (Gordon et al. 2011) campaigns on people's attitudes and behaviour.

The panel-based data used in Chapters 5 and 6 is better suited to establishing a causal relationship between communication and changes in people's perceptions and actions (Mertens 2015). However, previous research by Howell (2014) has shown that long-term research also suffers from difficulties in attributing observed changes in individual attitudes and behaviour to climate change communication. This is because individuals gather information about climate change from many different sources that have conflicting messages and content (Arlt et al. 2011). Chapter 5 dealt with this issue, however, by asking

individuals about the influence of climate change communication and other factors on their recent forest management decisions.

One drawback of the thesis is that forest-related values were not considered in Chapters 3 and 4. The questionnaire for these two chapters included questions about forest owners' domain-specific values. However, the analysis of forest values was dropped from both chapters in response to comments received during the review process for Paper 1 (Chapter 3).[11] To address this shortcoming, Chapter 6 examined the influence of forest values on personal engagement with adaptation. Another drawback of the thesis is that it is mostly limited to self-efficacy beliefs and does not consider outcome beliefs, or personal beliefs about the effectiveness of specific forest management outcomes. Investigating the influence of specific outcome beliefs on personal engagement with adaptation would have been beyond the scope of the thesis and would have required a stronger focus and practical understanding of silviculture research. In line with the overall objective of the thesis, Chapter 6 focused instead on the effect of communication on personal opinions about forest management options. Another minor limitation of Chapters 5 and 6 is that the questionnaires sent out before and after the focus group meeting did not ask forest owners whether they attributed personal experience of extreme events to climate change. This shortcoming was addressed in the follow-up interviews, which asked forest owners to relate personal experience to climate change and whether their views had changed since before the focus group meetings.

The greatest limitation of this thesis, however, is that its analytical focus was mostly limited to psychological barriers of personal engagement with adaptation. This approach was taken based on the intrapsychic and behavioural models discussed in Chapter 2 and following the example of previous research on individual adaptation (Blennow et al. 2012) and climate change communication (Wolf and Moser 2011). Chapter 3 offered some insights into non-psychological factors but was still limited to determinants of individual adaptive capacity. Even though the APA's model includes social moderators, the thesis did not ask specific questions about the influence of contextual factors – institutional norms and socio-economic conditions – on personal engagement with adaptation or how these factors influence how individuals respond to climate change communication. This shortcoming was addressed by

[11] The reviewers argued that the manuscript was too long and that the paper should focus exclusively on the comparison between the two groups of forest owners to infer knowledge about the relationship between communication and personal engagement with adaptation.

discussing the results of the thesis in the context of the Swedish forest sector in Chapters 4 and 6 as well as in the previous section.

7.3 Overall conclusions

This thesis asked whether climate change communication can promote individual engagement with climate change. To answer this question, the thesis drew lessons from two communication projects that involved forest owners in Sweden: one that followed the transmission-orientated approach and one that followed the deliberation-based approach to science communication (Ballantyne 2016). To measure the effect of communication on individual engagement with adaptation, the thesis applied a deductive approach to test assumptions about the influence of various intrapsychic conditions on personal intentions and behaviour related to adaptation. Based on its findings, the thesis draws eight conclusions.

First, the findings of this thesis suggest that climate change communication by itself has little effect on personal intentions and behaviour related to climate change adaptation. Instead of dismissing it as ineffective, however, climate change communication needs to be understood as a complex socio-psychological processes that is influenced by intrapsychic factors, institutions, socio-economic conditions and the social discourse on climate change. Thus, the ability of communication to promote engagement with climate change may be better understood in terms of its influence on the psychological drivers that make it more likely that individuals will take adaptive action in the future.

Second, the thesis highlights the limits of understanding individual adaptation purely as a psychological process determined by intrapsychic conditions. While the thesis showed that personal appraisal of climate risk, concern and personal experience of extreme events, as well as attribution of these experiences to climate change and self-efficacy beliefs are all significant predictors, they only explain a small share of the variation in perceived need and intention to adapt to climate change. It can be argued that adding other psychological drivers such as place attachment (Scannell and Gifford 2013) or personal beliefs about who should be responsible for adaptation (Howell et al. 2016) could increase the explanatory power of the psychological approach to individual engagement with adaption. However, recent research has confirmed that even when taking these additional factors into account, intrapsychic conditions only appear to have a weak to medium-strength effect on adaptive behaviour (van Valkengoed and Steg 2019).

Third, the findings of this thesis also indicate that institutional norms require greater attention in order to understand personal engagement with adaptation and the potential for climate change communication to promote adaptive behaviour. The results of the thesis and the literature (Andersson et al. 2018) suggest that institutional norms influence how people frame climate change risk and how they appraise adaptation options and their personal ability to adapt to climate change. This might suggest that communication intervention should align more closely with institutional norms to make adaptation appear easier. Given the threat from sudden and irreversible climate change impacts (e.g. Solomon et al. 2009), however, it may be necessary for communication to help its audience challenge the norms that favour a business-as-usual approach to adaptation. This would require a greater focus on promoting transformative learning (Vulturius and Gerger Swartling 2015), social mobilisation (Johnson 2012) and transformative collective action (Kates et al. 2012).

Fourth, the thesis has also offered insights into the value, complementarity and shortcomings of cross-sectional, longitudinal and mixed-methods data for studying individual engagement with adaptation and climate change communication. While cross-sectional data has its limitations, the thesis still showed how it can be used to infer meaningful knowledge using regression analysis about the connection between climate change communication and individual engagement with climate change. Longitudinal data, however, is undoubtedly better suited for learning about the long-term effects of climate change. Both cross-sectional and longitudinal data, however, are insufficient for understanding how people make sense of climate change communication and the influence of other sources of climate information. Qualitative data is needed to understand how people interpret climate information in relation to experience-based knowledge, institutional norms, personal values and decision-making circumstances. Furthermore, retrospective studies on personal experience of science-based communication and climate-related risk can also help understand how climate change communication is perceived. Taken together, research about climate change communication should deploy a multi-pronged approach that combines repeated cross-sectional surveys with mixed-methods panel data (Ruspini 1999).

Fifth, insights from this thesis and the ongoing discussion on motivated reasoning vs. bounded rationality (Kahan and Carpenter 2017; van der Linden et al. 2017) highlight the need to improve how research measures the effects of climate change communication so that experiences with different communication approaches and contexts can be compared

and synthesised (Gifford et al. 2011). Efforts to standardise the science of science communication are already under way (Kahan 2015). A recent meta-analysis of the drivers of adaptive behaviour (van Valkengoed and Steg 2019) and advances in systematic reviews of the scientific and grey literature using stakeholder engagement (Haddaway et al. 2017) point the way to a more sophisticated and participatory approach to synthesising and testing communication interventions.

Sixth, the thesis offers valuable practical insights about the importance of tailored knowledge to researchers and practitioners of climate change communication. Its findings support the assumption that communication can positively influence self-efficacy beliefs (Bostrom et al. 2013) and that self-efficacy beliefs are of great importance to personal intentions to take adaptive measures (van Valkengoed and Steg 2019). However, the results from Chapter 6 and the literature (Lidskog and Sjödin 2014) also suggest that more focus should be put on demonstrating and co-developing knowledge about climate change risk and adaptation measures that audiences find relatable, effective and actionable (Bremer and Meisch 2017). To achieve this objective, climate change communication must combine expert and non-expert knowledge (Wibeck 2013).

Seventh, while the thesis shows that climate change communication can enhance trust in climate science (Goodwin and Dahlstrom 2014), it also highlights that the credibility of communication is a multifaceted issue that involves the audience's trust not just in the source and the content but also in the process of how information is produced and communicated (Asplund 2018). The results also suggest that the perceived uncertainty, ambiguity and lack of practical value of climate information provide important reasons for the lack of trust in climate science (Whitmarsh 2011), and that climate change communication needs to address these issues if it is to achieve its objectives (Markowitz and Guckian 2018).

Eighth, to ensure that climate change communication is science-based, actionable and credible, lasting relationships between scientists, practitioners and audiences are needed (Moser 2016). Boundary organisations can facilitate relationship building and learning within and across different communities of practice (Cash 2000) and help bridge the climate information usability gap (Lemos et al. 2012). In addition, boundary organisations that follow the deliberation-based approach to communication may also help individuals better understand and act on complex and uncertain climate change information (Blades et al.

2016). In the Swedish forest sector, the role of boundary organisations could be played by forest owner associations.

Ninth, the thesis also offers valuable insights for the debate about the transmission-orientated approach vs the deliberation-orientated approach to science communication. Results presented here indicate that neither approach can guarantee comprehensive change in public opinion and increased level of personal engagement with scientific information and knowledge. This could support the literature arguing that science communication needs to be complemented by participatory activities that involve joint knowledge development, problem solving and decision making (Bubela et al 2009). However, findings of this thesis also suggest that the limited effect of communication interventions on individual engagement with adaptation is partly due to the lack of attention research and practice of science communication are paying to the influence of social and institutional norms on the public understanding of science. This highlights the need for what Irwin (2014) has called 'third order thinking' in science communication that situates science–public relations in its context and that engages with the heterogeneity, conditionality and disagreement between public, scientific, institutional, political and ethical visions of change. Importantly, this does not imply that science communication should give up on the idea to improve public understanding of scientific knowledge (Brossard and Lewenstein 2010). Instead, it should embrace the complexity of combining insights and activities of the deficit, deliberation and participatory model of science communication (Metcalfe 2019).

7.4 Recommendations for future research

The limitations and conclusions of this thesis discussed above suggest the following areas for future research:

a) More longitudinal, mixed-methods research is needed to gain a more in-depth and contextualised understanding of the effect of climate change communication on individual engagement with adaptation. For the purpose of evaluation and lesson learning, this research should strive to be comparable and transparent by, for example, using common research principles, protocols and methods, and disclosing methods before they are implemented. Lessons can be learned in this regard from psychology and public health research. Studies that aim to synthesise findings on communication interventions should make use of systematic review methodology.

b) Beliefs about adaptation outcomes and basic values – two issues that have been beyond the scope of this thesis – should also be investigated in greater detail. Research on people's perceptions of the effectiveness of adaptation options could help to explain why engagement with adaptation has remained low and what specific knowledge is needed to promote adaptative behaviour. Better knowledge about the effects of basic values and motivated reasoning could also be instrumental in sparing adaptation the same fate as mitigation of ending up in the quagmire of political polarisation.

c) Future research should place a greater focus on the role of institutions as barriers to personal engagement with climate change adaptation – including how individuals appraise risk and adaptation options, and their intentions and ability to take adaptive measures. This research should also examine the influence of descriptive norms – perceptions of whether others are taking adaptive action – and injunctive norms – perceptions of whether adaptation will be approved or disapproved of by others. It would be interesting to see whether climate change communication can overcome these norms or use them to create opportunities for collective action.

d) More attention should be directed to boundary organisations at the interface between research, science communication and resource management. Research could examine how these organisations facilitate knowledge transfer, deliberation and multilevel learning. It should also examine how boundary organisations can be successful at creating credible, science-based and actionable knowledge. Rather than trying to replicate the conditions of boundary organisations, researchers should engage with existing boundary organisations or organisations that can take on such a role.

e) Future research should also investigate the complementarity of communication interventions and structural measures for promoting adaptation. This type of research could provide tangible knowledge for decision makers on how to design interventions that combine communication with monetary incentives for adaptive behaviour. Critical research could also highlight the limits of communication and the need to remove structural barriers to adaptation.

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Appendices

Appendix 1: Questionnaire used in Chapters 3 and 4

Translated from the original Swedish.

1. How much forest do you own (if you own your forest together with others, please state how much forest you own together with your co-owners)?

☐ 1-5 ha	☐ 51-100 ha	☐ 401 – 1000 ha
☐ 6-20 ha	☐ 101-200 ha	☐ >1000 ha
☐ 21-50 ha	☐ 201-400 ha	☐ Don't know

2. How long have you been a forest owner?

☐ 0-5 years	☐ 16-25 years	☐ 41-60 years
☐ 6-15 years	☐ 26-40 years	☐ 61- > years

3. I what county do you own forest?

☐ Blekinge	☐ Jämtland	☐ Norrbotten	☐ Uppsala
☐ Dalarna	☐ Jönköping	☐ Skåne	☐ Värmland
☐ Gotland	☐ Kalmar	☐ Stockholm	☐ Västerbotten
☐ Gävleborg	☐ Kronoberg	☐ Södermanland	☐ Västernorrland
☐ Halland	☐ Västmanland	☐ Östergötland	☐ Örebro
☐ Västra Götaland			

4. Is your forest certified?

☐ Yes, FSC, since ____	☐ No
☐ Yes, PEFC, since ____	☐ Don´t know

5. How important is the income from your forest for your total household income?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐
Not at all important				Very important	Don´t know

6. What do you consider important objectives for you as a forest owner? Please rate the following objectives on a scale from 1 = “Not at all important” to 5 = “Very important”

	Strongly disagree				**Strongly agree**
Objectives	1	2	3	4	5
Timber production	☐	☐	☐	☐	☐
Outdoor lifestyle	☐	☐	☐	☐	☐
Liquidity reserve	☐	☐	☐	☐	☐
Environmental protection	☐	☐	☐	☐	☐
Tax planning	☐	☐	☐	☐	☐
Mitigating climate change (emission reduction or carbon sequestration)	☐	☐	☐	☐	☐
Mushroom and berry picking	☐	☐	☐	☐	☐
Grazing	☐	☐	☐	☐	☐
Soil protection	☐	☐	☐	☐	☐
Biofuel production	☐	☐	☐	☐	☐
Hunting	☐	☐	☐	☐	☐
Preserving forest landscape	☐	☐	☐	☐	☐
Income generation	☐	☐	☐	☐	☐
Water protection	☐	☐	☐	☐	☐
Keeping Forestry tradition	☐	☐	☐	☐	☐
Return on investment	☐	☐	☐	☐	☐

7. Please respond to the following statements on a scale from 1 = “Strongly disagree” to 5 = “Strongly agree”

Statements	**Strongly disagree** 1	2	3	4	**Strongly agree** 5	**Don’t know**
I am very concerned about the global risk of climate change.	☐	☐	☐	☐	☐	☐
I am very concerned about the risk of climate change to my own forest.	☐	☐	☐	☐	☐	☐
I consider the global risk of climate change to be very serious.	☐	☐	☐	☐	☐	☐
I consider the risk of climate change to my own forest to be very serious.	☐	☐	☐	☐	☐	☐
I believe that my own forest is resilient enough to cope with climate change.	☐	☐	☐	☐	☐	☐
I believe that I have enough knowledge to adapt my forest to climate change.	☐	☐	☐	☐	☐	☐
I believe that I am capable of adapting my forest to climate change.	☐	☐	☐	☐	☐	☐
I consider climate science to be trustworthy.	☐	☐	☐	☐	☐	☐
I need to take climate change into greater consideration.	☐	☐	☐	☐	☐	☐

8. How will climate change impact your forest. Please respond on a scale from 1 = “Very negative” to 5 = “Very positive”

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Very negative — Very positive — Don´t know

9. Have you observed any changes in the weather or climate over the last 30 years?

☐ Yes ☐ No

10. Has your forest been affected by extreme weather events in the last ten years?

- ☐ Yes, storm Gudrun (2005)
- ☐ Yes, storm Per Dalarna (2007)
- ☐ Yes, storm Dagmar (2011)
- ☐ Yes, storms and extreme weather evens during fall and winter 2013/2014
- ☐ Yes, ____
- ☐ No
- ☐ Don't know

11. Please respond to the following statement on a scale from 1 = "Strongly disagree" to 5 = "Strongly agree"

Statement	**Strongly disagree** 1	2	3	4	**Strongly agree** 5	**Don't know**
I believe that at least one of these extreme events has been caused by climate change.	☐	☐	☐	☐	☐	☐

12. What is your opinion about the seriousness of following risks for your forest today? Please respond on a scale from 1 = "Not at all serious" to 5 = "Very serious"

Risks	**Not at all serious** 1	2	3	4	**Very serious** 5	**Don't know**
Storms	☐	☐	☐	☐	☐	☐
Flooding	☐	☐	☐	☐	☐	☐
Snow breakage	☐	☐	☐	☐	☐	☐
Browsing by herbivores	☐	☐	☐	☐	☐	☐
Frost damage	☐	☐	☐	☐	☐	☐
Drought and forest fire	☐	☐	☐	☐	☐	☐
Damage due to poorer ground conditions	☐	☐	☐	☐	☐	☐
Pests such as bark beetles and root rot	☐	☐	☐	☐	☐	☐
Loss of biodiversity	☐	☐	☐	☐	☐	☐

13. How do you think these risks will change in next 50 years? Please respond on a scale from 1 = “Become a lot less serious” to 5 = “Become a lot more serious”

	Will become a lot less serious				**Will become a lot more serious**	**Don’t know**
Risks	1	2	3	4	5	
Storms	☐	☐	☐	☐	☐	☐
Flooding	☐	☐	☐	☐	☐	☐
Snow breakage	☐	☐	☐	☐	☐	☐
Browsing by herbivores	☐	☐	☐	☐	☐	☐
Frost damage	☐	☐	☐	☐	☐	☐
Drought and forest fire	☐	☐	☐	☐	☐	☐
Damage due to poorer ground conditions	☐	☐	☐	☐	☐	☐
Pests such as bark beetles and root rot	☐	☐	☐	☐	☐	☐
Loss of biodiversity	☐	☐	☐	☐	☐	☐

14. What is your opinion about the effectiveness of the following forest management measures to deal with weather- and climate-related risks? Please respond on a scale from 1 = “Not at all effective” to 5 = “Very effective”

Forest management measures	**Strongly disagree** 1	2	3	4	**Strongly agree** 5	**Don’t know**
Taking local conditions into greater consideration during planting or final felling	☐	☐	☐	☐	☐	☐
Shorter of rotation period between planning and final felling.	☐	☐	☐	☐	☐	☐
Increasing mix and diversity of tree species	☐	☐	☐	☐	☐	☐
Harder pre-commercial thinning and cutting	☐	☐	☐	☐	☐	☐
Forest management approaches that avoid clear-cutting (e.g. continuous-cover forest management)	☐	☐	☐	☐	☐	☐
Measures against insects and fungi	☐	☐	☐	☐	☐	☐
Improvements to drainage ditches	☐	☐	☐	☐	☐	☐
Salvage cutting and reforestation after storms	☐	☐	☐	☐	☐	☐
Investment into new equipment and roads	☐	☐	☐	☐	☐	☐
Insurance	☐	☐	☐	☐	☐	☐
Wildlife management	☐	☐	☐	☐	☐	☐

15. Which of these measures have to you taken in the last ten years and which five measures to you think are most effective to address climate change?

Forest management measures	**Measures taken in the last ten years**	**Most effective to address climate change**
Taking local conditions into greater consideration during planting and final felling	☐	☐
Shorter of rotation period between planting and final felling.	☐	☐
Increasing mix and diversity of tree species	☐	☐
Harder pre-commercial thinning and cutting	☐	☐
Forest management approaches that avoid clear-cutting (e.g. continuous-cover forest management)	☐	☐
Taking measures against insects and fungi	☐	☐
Improvements to drainage ditches	☐	☐
Salvage cutting and reforestation after storms	☐	☐
Investment into new equipment and roads	☐	☐
Having forest insurance	☐	☐
Wildlife management	☐	☐

16. How important was your own knowledge and experience with climate change when you decide to take one or more of these measures?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Not at all important — Very important — Don´t know

17. Are you planning to take risk-mitigating measures to address climate change in the coming five years?"

☐ Yes ☐ No

18. Are you a member of a forest owner association?

☐ Yes, Norra Skogsägare ☐ Yes, Mellanskog
☐ Yes, Skogsägarna Norrskog ☐ Yes, Södra Skogsägare
☐ Other, ____ ☐ No

19. Have you taken part in one of the following activities?

- ☐ Yes, Kraftsamling Skog
- ☐ Yes, Krafthandling Skog
- ☐ Yes, individual consultations about climate change by the Swedish Forest Agency
- ☐ No, I have not taken part in any of those activities
- ☐ Yes, Kometprogrammet
- ☐ Yes, courses or evening meetings about climate change by the Swedish Forest Agency
- ☐ Other, ____

20. Are you a man or a woman?

- ☐ Man
- ☐ Woman

21. What year where you born?

19 ____

22. Where do you live?

- ☐ Stockholm, Gothenburg or Malmö
- ☐ In a larger town (more than 50.000 inhabitants)
- ☐ In a medium-sized town (between 20.000 and 50 inhabitants)
- ☐ In a small town (less than 20.000 inhabitants)
- ☐ In the countryside

23. What is your highest educational degree?

- ☐ Primary school degree
- ☐ Secondary school degree
- ☐ University degree (up to three years)
- ☐ University degree (four years or more)
- ☐ Other

24. What is your occupation?

- ☐ Employed
- ☐ Student
- ☐ Permanent sick leave
- ☐ Self-employed
- ☐ Retired
- ☐ Unemployed
- ☐ Parental leave
- ☐ Other, ____

25. What is your monthly household income after taxes and including benefits in SEK?

- ☐ 5000 or less
- ☐ 5001 – 10000
- ☐ 10001 – 15000
- ☐ 150001 – 20000
- ☐ 20001 – 25000
- ☐ 25000 – 30000
- ☐ 30001 - 35000
- ☐ 35001 – 40000
- ☐ 40001 – 45000
- ☐ 45001 – 50000
- ☐ 50001 – 55000
- ☐ 55001 or more

26. Do you have any comments?

____

Appendix 2: Ex-ante questionnaire with participants in the focus group meetings (T-0)

Translated from the original Swedish. This questionnaire was distributed to forest owners at the beginning of the first group meeting in spring 2014.

1. What year where you born?

   19 ____

2. How much forest do you own (if you own your forest together with others, please state how much forest you own together with your co-owners)?

☐ 1-5 ha	☐ 51-100 ha	☐ 401 – 1000 ha
☐ 6-20 ha	☐ 101-200 ha	☐ >1000 ha
☐ 21-50 ha	☐ 201-400 ha	☐ Don't know

3. How long have you been a forest owner?

☐ 0-5 years	☐ 16-25 years	☐ 41-60 years
☐ 6-15 years	☐ 26-40 years	☐ 61- > years

4. Is your forest certified?

☐ Yes, FSC, since ____	☐ No
☐ Yes, PEFC, since ____	☐ Don´t know

5. How important is the income from your forest for your total household income?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐
Not at all important				Very important	Don´t know

6. What do you consider important objectives for you as a forest owner? Please rate the following objectives on a scale from 1 = “Not at all important” to 5 = “Very important”

	Strongly disagree				**Strongly agree**
Objectives	1	2	3	4	5
Timber production	☐	☐	☐	☐	☐
Outdoor lifestyle	☐	☐	☐	☐	☐
Liquidity reserve	☐	☐	☐	☐	☐
Environmental protection	☐	☐	☐	☐	☐
Tax planning	☐	☐	☐	☐	☐
Mitigating climate change (emission reduction or carbon sequestration)	☐	☐	☐	☐	☐
Mushroom and berry picking	☐	☐	☐	☐	☐
Grazing	☐	☐	☐	☐	☐
Soil protection	☐	☐	☐	☐	☐
Biofuel production	☐	☐	☐	☐	☐
Hunting	☐	☐	☐	☐	☐
Preserving forest landscape	☐	☐	☐	☐	☐
Income generation	☐	☐	☐	☐	☐
Water protection	☐	☐	☐	☐	☐
Keeping forestry tradition	☐	☐	☐	☐	☐
Return on investment	☐	☐	☐	☐	☐

7. Please respond to the following statements on a scale from 1 = “Strongly disagree” to 5 = “Strongly agree”

Statements	**Strongly disagree** 1	2	3	4	**Strongly agree** 5	**Don’t know**
I am very concerned about the global risk of climate change.	☐	☐	☐	☐	☐	☐
I am very concerned about the risk of climate change to my own forest.	☐	☐	☐	☐	☐	☐
I consider the global risk of climate change to be very serious.	☐	☐	☐	☐	☐	☐
I consider the risk of climate change to my own forest to be very serious.	☐	☐	☐	☐	☐	☐
I believe that my own forest is resilient enough to cope with climate change.	☐	☐	☐	☐	☐	☐
I believe that I have enough knowledge to adapt my forest to climate change.	☐	☐	☐	☐	☐	☐
I consider climate science to be trustworthy.	☐	☐	☐	☐	☐	☐
I need to take climate change into greater consideration.	☐	☐	☐	☐	☐	☐

8. How will climate change impact your forest. Please respond on a scale from 1 = “Very negative” to 5 = “Very positive”

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Very negative — Very positive — Don´t know

9. Have you observed any changes in the weather or climate over the last 30 years?

☐ Yes ☐ No

10. What is your opinion about the seriousness of following risks for your forest today? Please respond on a scale from 1 = “Not at all serious” to 5 = “Very serious”

	Not at all serious				**Very serious**	**Don’t know**
Risks	1	2	3	4	5	
Storms	☐	☐	☐	☐	☐	☐
Flooding	☐	☐	☐	☐	☐	☐
Snow breakage	☐	☐	☐	☐	☐	☐
Browsing by herbivores	☐	☐	☐	☐	☐	☐
Frost damage	☐	☐	☐	☐	☐	☐
Drought and forest fire	☐	☐	☐	☐	☐	☐
Damage due to poorer ground conditions	☐	☐	☐	☐	☐	☐
Pests such as bark beetles and root rot	☐	☐	☐	☐	☐	☐
Loss of biodiversity	☐	☐	☐	☐	☐	☐

11. How do you think these risks will change in next 50 years? Please respond on a scale from 1 = “Will become a lot less serious” to 5 = “Will become a lot more serious”

	Will become a lot less serious				**Will become a lot more serious**	**Don’t know**
Risks	1	2	3	4	5	
Storms	☐	☐	☐	☐	☐	☐
Flooding	☐	☐	☐	☐	☐	☐
Snow breakage	☐	☐	☐	☐	☐	☐
Browsing by herbivores	☐	☐	☐	☐	☐	☐
Frost damage	☐	☐	☐	☐	☐	☐
Drought and forest fire	☐	☐	☐	☐	☐	☐
Damage due to poorer ground conditions	☐	☐	☐	☐	☐	☐
Pests such as bark beetles and root rot	☐	☐	☐	☐	☐	☐
Loss of biodiversity	☐	☐	☐	☐	☐	☐

12. Which of these measures have to you taken in the last ten years and which five measures to you think are most effective to address climate change?

Forest management measures	**Measures taken in the last ten years**	**Most effective to address climate change**
Taking local conditions into greater consideration during planting or final felling	☐	☐
Shorter of rotation period between planting and final felling.	☐	☐
Increasing mix and diversity of tree species	☐	☐
Harder pre-commercial thinning and cutting	☐	☐
Forest management approaches that avoid clear-cutting (e.g. continuous-cover forest management)	☐	☐
Taking measures against insects and fungi	☐	☐
Improvements to drainage ditches	☐	☐
Salvage cutting and reforestation after storms	☐	☐
Investment into new equipment and roads	☐	☐
Having forest Insurance	☐	☐

13. Are you a member of a forest owner association?

☐ Yes, Norra Skogsägare
☐ Yes, Skogsägarna Norrskog
☐ Other, ____
☐ Yes, Mellanskog
☐ Yes, Södra Skogsägare
☐ No

14. Have you taken part in one of the following activities?

☐ Yes, Kraftsamling Skog
☐ Yes, Krafthandling Skog
☐ Yes, individual consultations about climate change by the Swedish Forest Agency
☐ No, I have not taken part in any of those activities
☐ Yes, Kometprogrammet
☐ Yes, courses or evening meetings about climate change by the Swedish Forest Agency
☐ Other, ____

Appendix 3: Agenda of the first focus group meeting November 2013

Translated from the original Swedish.

Mistra-SWECIA case study about climate change adaptation in the Swedish forest sector

6:00 pm Welcome and introduction

- Welcome
- Round of introduction of participants and the team of meeting leaders, Karin André and Gregor Vulturius
- Rules for discussions and housekeeping: There are now wrong statements, question or answers. The two meeting leaders are here to guide the discussion but won't steer the conversation. Participation in all three group meetings is voluntary. We would like to record the conversation for research purposes. Everything that is being said or written will be kept confidential.
- Hand-out of the ex-ante questionnaire. Participants are given 15 to fill in the questionnaire
- Presentation of the Mistra-SWECIA program and short description of the three group meetings.

6.30 pm First exercise: Forest management

- Participants are asked to locate their forest property or properties on a map.
- Participants are then asked to write down on post-it notes 3-5 things they consider important when it comes to forest management. This could include objectives, preferences for certain management options, risk etc.
- Post-it notes are put up on a white board by the meeting leaders to facilitate a group discussion

7:30 pm Second exercise: Risk perceptions

- Participants are asked to list five risk, challenges and problem they are facing today and in the future as forest owners. These issues don't have to relate to climate change
- Participants are then asked which of these issues they are dealing with today, and which issues are difficult to deal with and why.

7:45 pm Third exercise: Views about climate change adaptation

- Open discussion about what climate change could mean for forest owners. The meeting leaders ask the following questions:
    - "We are interested in your personal reflections and views. What comes to your mind when you are asked about climate change?"
    - "Do you think about climate change and how it relates to your forest?"
    - "Have you talked to someone about climate change? With whom and in what context?

8:20 pm Closing of the meeting

- Short summary of the meeting
- Announcement of the date of the next meeting
- Participants are asked to evaluate the meeting: What has worked and what didn't, what was interesting and what was missing?

8.30 pm: End of the meeting

Appendix 4: Agenda of the second focus group meeting Winter 2014

Mistra-SWECIA second focus group meeting: Future climate and risk management

6:00 pm Welcome and introduction

- Welcome
- Short presentation of the agenda
- Introduction of the researchers from SMHI and Lund University and of new forest owners that have joint since the first group meeting
- Short summary of the first group meeting:
    - Forest owners' objectives
    - Risk related and unrelated to climate change
    - Opinions about climate change adaptation and risk mitigating measures

6:15 pm Future climate change and its impacts: presentation and interactive discussion

- Future climate change, presentation by researcher from SMHI
    - Discussion about climate scenarios, impacts, climate science, uncertainty etc.
    - If time allows, participants are asked about their sources of information about climate change
- Climate change impacts, risk management and adaptation, presentation by researcher from Lund University
    - Discussion about climate impacts for the county where the meeting takes place
    - Discussion about the matrix of climate-related risk management approaches

7:30 pm Discussion about risk management and adaptation strategies

- Participants are asked to write down on post-it notes measures and strategies to address risks related to biodiversity, Pests, weather, climate and economic losses. Owners are asked to follow the matric of climate-related risk management approaches and list reactive, active and proactive measurers.
- The matrix of climate-related risk management approaches is drawn on the white-board

- Participants are asked to tape their post-it notes onto the matrix
- Participants are then asked to discuss risk management measures and strategies for each category of the matrix, including conflicts between different measures and strategies
- At the end of this exercise, participants are asked to give feedback how useful the matrix is to evaluate risks and risk mitigation measures and strategies. They are also asked what format they would prefer and what information they are currently using.

8.20 pm Closing

- Short summary of the meeting
- Announcement of the date of the next meeting
- Participants are asked to evaluate the meeting: What has worked and what didn't, what was interesting and what was missing?

8.30 pm: End of the meeting

Appendix 5: Presentation about climate change

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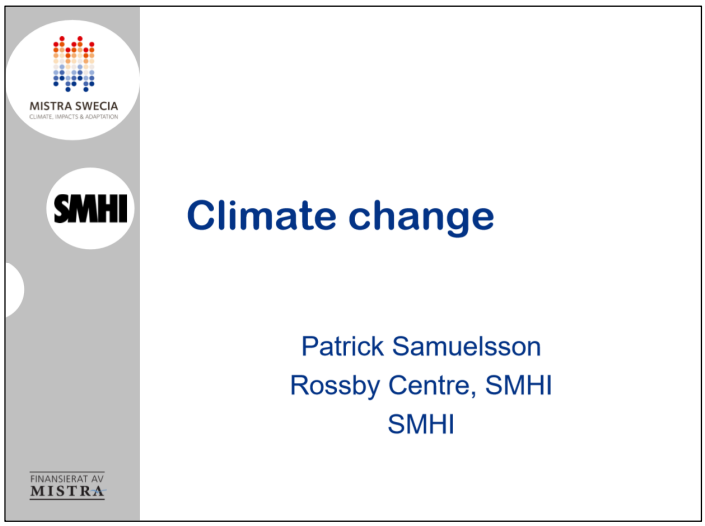
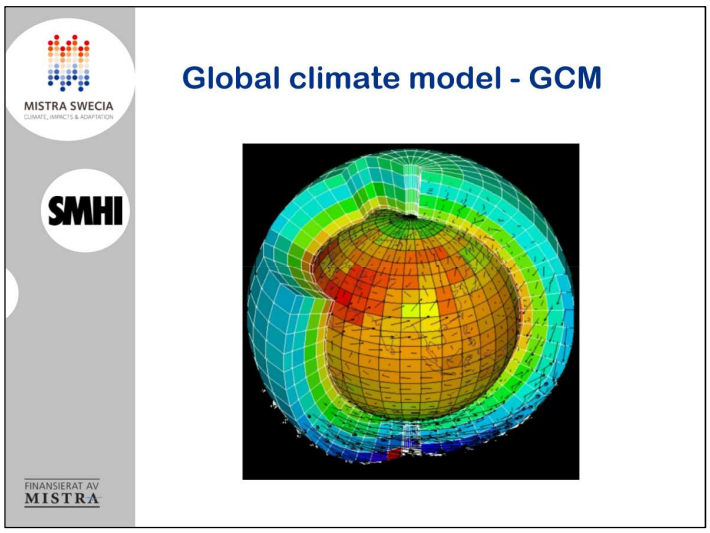
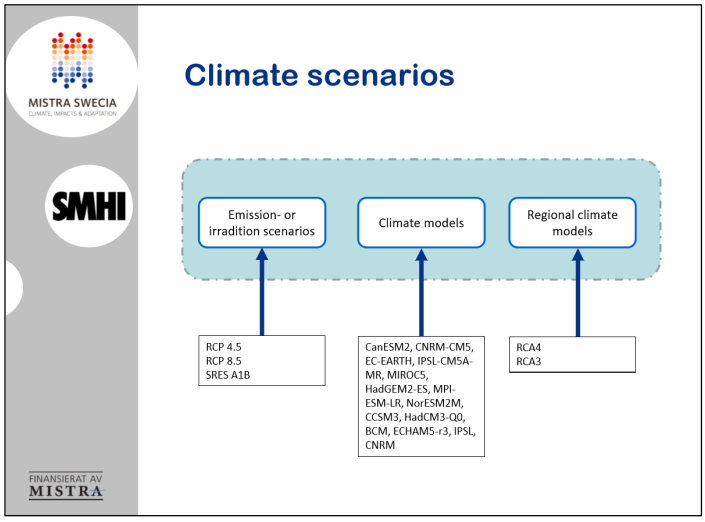
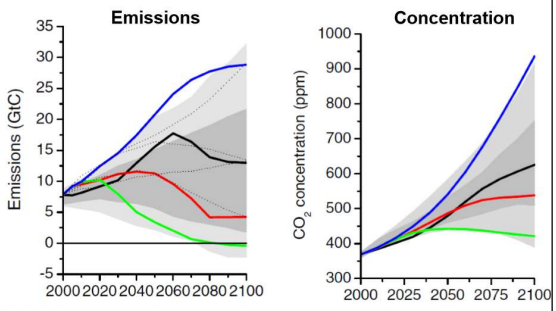






Emission scenarios (RCP)



RCP 8.5 — Continuously increasing emissions!
RCP 6.0
RCP 4.5 — Decrease from 2050.
RCP 2.6 (3-PD) — Decrease from 2020. Uptake within 100 years!

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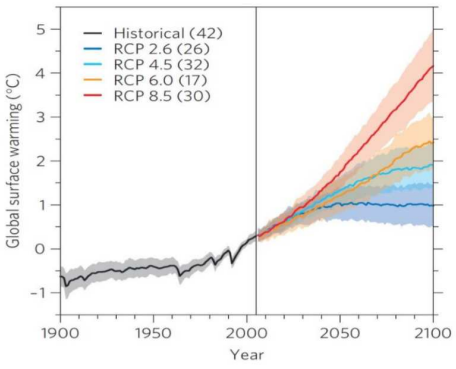
Ensemble of scenarios for future temperature

Ensembles are composed of multiple GCM simulations



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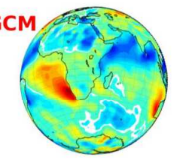
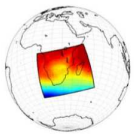
Regional climate models - RCM

GCM



Calculations made for 100 – 400 km large grid cells

RCM



Calculations made for 10 – 50 km large grid cells

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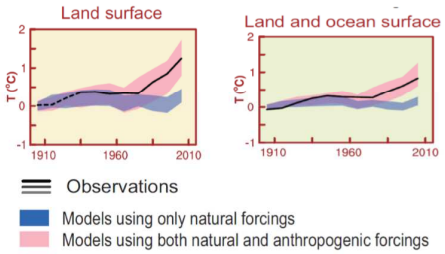
Are models correct?



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Climate models - IPCC

Working Group I (WGI): The Physcial Science Basis

GCMs

&

RCMs

Fourth Assessment Report (AR4) 2007

Fifth Assessment Report (AR5) September 2013

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IPCC AR5 WGI: The facts

IPCC reports are a synthesis of already published and reviewed papers in scientific journals

The latest report involved:

> **9200** scientific publications

14 chapters (ca. 2000 pages, 1250 figures)

> 1000 nominated authors from 63 countries

209 main authors (including two Swedish: Markku Rumukainen + Deliang Chen)

50 editors from **39** countries that reviewed **> 54000** comments from ca. **1100** reviewers

> 600 contributing authors from **32** countries

> **2 million** gigabites of numerical data from simulations of climate models (including two models from SMHI

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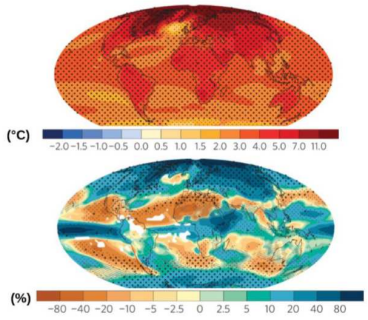
Temperature & Precipitation

Differences of a 20 year period (2090 – 1995) for dec-feb with RCP 8.5



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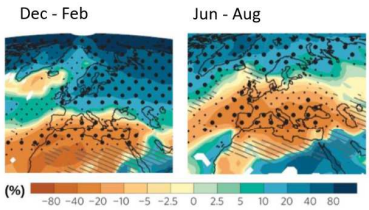
Precipitation

Differences of a 20 year period (2090 – 1995)



- Very good consistency between different models
- Good consistency between different models
- 80% of models don't show any significant changes
- Discernable changes exist but point to different directions

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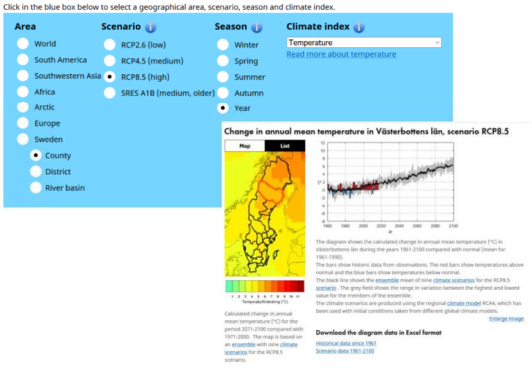
SMHI's interactive web application

https://www.smhi.se/en/climate/climate-scenarios/sweden/county/rcp85/year/temperature



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Skåne county

Climate change according to RCP 8.5 by 2050

Temperature increases in all seasons and especially in winter. Annual mean temperature increases by about 2°C, winter 2-3°C.

Minimum temperatures are increasing more than maximum temperatures. Minimum daily mean temperature in winter will increase 3-6°C, maximum daily mean temperature in summer will increase 2-3°C.

Annual precipitation increases by around 10% and falls almost ever as rain. However, there is high uncertainty between different models. Extreme precipitation increases.

No trend in wind speeds and storms but less groundwater formation during summer months. No increased risk of drought but less surface water. Vegetation period will be ca. 2 months longer.

Gävleborg county

Climate change according to RCP 8.5 by 2050

Temperature increases in all seasons but most strongly in winter. Mean annual temperature is expected to increase by 3°C, winter 3-5°C.

Minimum temperatures are increasing more than maximum temperatures. Minimum mean daily temperature in winter increases between 5-7°C. Maximum daily mean temperature in summer increases by 2°C.

Spring flood starts earlier with lower peaks. Winter floods becomes bigger. One month less of snow coverage and less frozen ground.

Annual precipitation increases by around 20%. Precipitation falls more often as rain than snow. Extreme precipitation events also become more frequent.

Now indication that risks from storms and wind gusts will change.

Jämtland county

Climate change according to RCP 8.5 by 2050

Temperature increases all seasons, but especially in winter. Annual mean temperature will increase by about 3°C, winter 3-5°C.

Minimum temperatures are increasing more than maximum temperatures. Minimum mean daily temperature in winter will increase 6-9°C, the highest average daily temperature in summer is increasing appr 2°C.

Annual precipitation increases by around 15%, more rain than snow. Also, extreme precipitation increases. Spring flood start earlier with lower peaks. Winter flood becomes bigger. Annual runoff increases by 10-20% by 2100.

Less of snow coverage and reduced frozen ground.

No change in the risk from wind speeds and storms but increasing risk from forest fires

Västerbotten county coast

Climate change according to RCP 8.5 by 2050

Temperature increases in all seasons and mostly in winter. Annual mean temperature increases by ca. 3°C and 4-5°C in winter. Minimum temperatures are increasing more than maximum temperatures. Minimum daily mean temperature in winter increases between 7-8°C, maximum daily mean temperature in summer will increase by 2°C.

Annual precipitation increases by around 20%. Precipitation falls more often as rain than snow. Extreme precipitation events also become more frequent. Spring floods start earlier with lower peaks. Fall floods increase.

Decrease in amount of snow by 15-35%. Period with snow coverage will be 1-2 months shorter. Less frozen ground in areas without snow coverage but can increase in some areas due to reduced snow depth.

Now change in the risk from storms and wind gusts.

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Links to further information

SMHI web application for climate scenarios:
https://www.smhi.se/klimat/framtidens-klimat/klimatscenarier/

Climate- and vulnerability analyses for each county
http://www.klimatanpassning.se/2.481/vem-har-ansvaret/lansvisa-klimat-och-sarbarhetsanalyser-1.25071

Website for climate change adaptation and forestry
http://www.klimatanpassning.se/Hur-paverkas-samhallet/Lantbruk-och-skogsbruk/skogsbruk-1.21503

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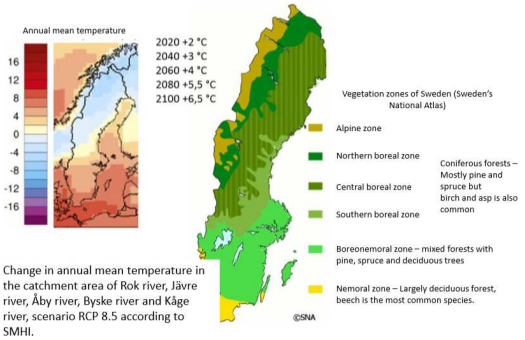
Appendix 6: Presentation about climate impacts and adaptation strategies for forest owners

Translated from the original Swedish and reproduced with the permission of the presenters.

Climate impacts and adaptation strategies for forest management in Sweden

Fredrik Lagergren and Anna Maria Jönsson
Department of Physical Geography and Ecosystem Science
Lund University

Future Climate



Change in annual mean temperature in the catchment area of Rok river, Järvre river, Åby river, Byske river and Kåge river, scenario RCP 8.5 according to SMHI.

Climate impacts – higher growth

Cause

- Longer vegetation period

But the trend is also due to

- More carbon dioxide in the atmosphere
- Nitrogen deposition in the soil
- Cultivated plants
- Improved silviculture methods
- Other tree species

Climate impacts – changing risks

Cause

- Faster reproduction of pests and biohazards
- New species
- Extreme weather events
- Trees are less adapted
- Milder winters

But

- New species are not necessarily tied to climate change
- Trees are become more vulnerable to storms, but storms don't become more frequen

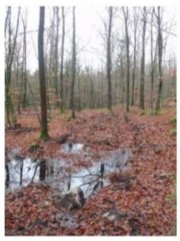
Climate impacts – changing ground conditions

Cause

- Shorter periods with ground frost
- More precipitation during winter
- Changing snow melt

But also

- More rejected tops and branches for fuel
- Improved machinery and equipment

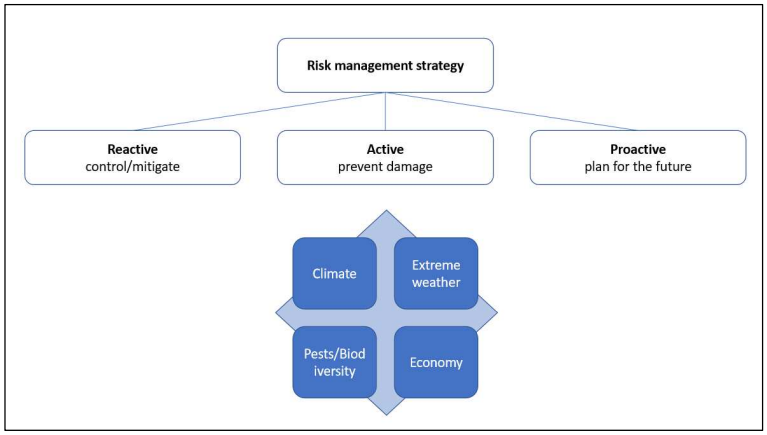


Connection between objectives, risks and forest management

Societal conditions

- Sweden's National Environmental Objectives
- Swedish Forest Act
- Certification

Forest owners' objectives	Risks
Continued production	Unexploited production potential Short-term production loss Long-term production loss
Return on investment	Poor return on investment Fines and legal costs
Biodiversity	Loss of species Loss of ecologically valuable habitats Negative impact of surrounding environment
Recreation	Worse conditions for recreation
Climate change mitigation	Reduction of sequestered carbon Loss in sequestration potential Emission of carbon dioxide and other greenhouse gases



Risk – Adaptation – Objectives

Avoid: Irreversible Loss of production capacity Extinction of species Severe damage caused by operation of heavy machinery		**Reactive: Manage damage** Snow breakage – restore Storm damage – restore Insects – monitor and control Frost or drought – additional planting Forest fire - fight
Active: Climate Forest roads Clean irrigation trenches Cleaning and pre-commercial thinning Rotation periods between planning and commercial felling Mix and diversity of tree species Local conditions	**Active: Biology** Wildlife management Root rot treatment Pine weevil control Bark beetle control Insect traps	**Active: Economy** Forest management plan Insurance Forest account Investments
Active: Extreme weather Insect traps Time of final felling Local conditions	**Active: Biodiversity** Nature reserve Voluntary set-aside Redlist Dead wood Forest edges Controlled fire	**Proactive** Keep future options New tree species New forest management strategies Development of new products Adapt to invasive pests

Example – Storm damage

Risks
- Unexploited production potential
- Short-term production loss
- Poor return on investment
- Less sequestered carbon
- Reduced sequestration potentia

Example – Storm damage

Decision	Category
Time for final felling Adoption of continious-cover forest management Plan for cleaning and pre-commercial thinning	Planing
Planting or natural regrowth Leave seed trees Choice of tree species Density and composition during planting	Final felling and replanting
Stand condition after cleaning Selection of tree species during cleaning	Cleaning
Type of thinning (high/low/cover) Choice of equipment Selection of tree species during thinning Intensity of thinning	Pre-commerical thinning
Fertilisation	Other

Example – Storm damage

Background factors

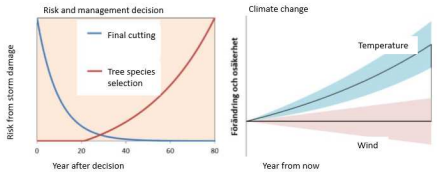
Forest conditions due to forest management: Rotation periods, selection of tree species, pre-commercial thinning and cutting

Triggering factors

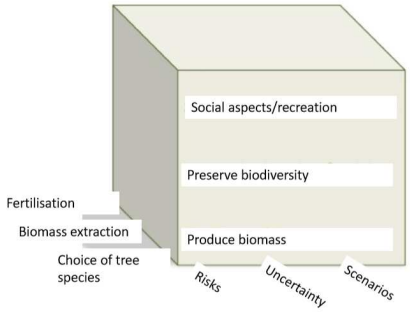
Wind speeds

Frozen ground

Short-term production loss
Poor return on investment
Reduced sequestration potential



Adaptation space



Appendix 7: Agenda of the third focus group meeting Spring 2014

Mistra-SWECIA third group meeting: Planning, knowledge and communication

6:00 pm Welcome and introduction

- Welcome
- Short introduction of today's agenda

6:10 pm Planning and decision making about adaptation measures

- Presentation of risk mitigation measures and strategies that participants had identified in the second meeting
- Participants are asked to list on post-it notes which of these measurers and strategies are easy, hard or impossible to implement and place them in three separate columns on a white board
- Participants are then asked to discuss each of three columns (easy, hard, impossible) and explain what factors they consider when they prioritize measures and strategies

7:20 pm Responsibility, leadership and networks

- Participants are asked to list important actors that they consult regarding forestry-related issues. Participants are presented with the result of the questionnaire from the first group meeting and asked if actors are missing or should be removed.
- Participants are then asked to place those actors on a white board and discuss how they are related to each other.
- Participants are then asked to rate actors in relation to how important they are to promote adaptation among Swedish forest owners. They are then asked to discuss how responsibility for adaptation should be divided between politicians, forestry companies, forest owner associations, researchers and individual forest owners

8:00 pm Knowledge and communication

- Participants are asked to give feedback on the two presentations about climate change impacts and risk mitigating measures given in second group meeting
- Discussion about the format and sources of relevant information and knowledge about climate risks and adaptation measures
- Participants are also asked how they view the credibility of climate science

8: 20 Closing

- Participants are invited to a workshop in November in Stockholm
- Each participant is asked how they wish to stay in touch with the Mistra-SWECIA program
- Participants are also informed that they will be contact by another researcher for a follow-up interview

8:30 pm End of the meeting

Appendix 8: First ex-post questionnaire with participants in the focus group meetings (T-1)

Translated from the original Swedish. This questionnaire was distributed to forest owners at the end of the third and last group meeting in spring 2014.

1. Please respond to the following statements on a scale from 1 = "Strongly disagree" to 5 = "Strongly agree"

Statements	**Strongly disagree** 1	2	3	4	**Strongly agree** 5	**Don't know**
I am very concerned about the global risk of climate change.	☐	☐	☐	☐	☐	☐
I am very concerned about the risk of climate change to my own forest.	☐	☐	☐	☐	☐	☐
I consider the global risk of climate change to be very serious.	☐	☐	☐	☐	☐	☐
I consider the risk of climate change to my own forest to be very serious.	☐	☐	☐	☐	☐	☐
I believe that my own forest is resilient enough to cope with climate change.	☐	☐	☐	☐	☐	☐
I believe that I have enough knowledge to adapt my forest to climate change.	☐	☐	☐	☐	☐	☐
I consider climate science to be trustworthy.	☐	☐	☐	☐	☐	☐
I need to take climate change into greater consideration.	☐	☐	☐	☐	☐	☐

2. How will climate change impact your forest. Please respond on a scale from 1 = "Very negative" to 5 = "Very positive"

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Very negative — Very positive — Don´t know

3. Have you observed any changes in the weather or climate over the last 30 years?

☐ Yes ☐ No

4. What is your opinion about the seriousness of following risks for your forest today? Please respond on a scale from 1 = “Not at all serious” to 5 = “Very serious”

	Not at all serious				**Very serious**	**Don’t know**
Risks	1	2	3	4	5	
Storms	☐	☐	☐	☐	☐	☐
Flooding	☐	☐	☐	☐	☐	☐
Snow breakage	☐	☐	☐	☐	☐	☐
Browsing by herbivores	☐	☐	☐	☐	☐	☐
Frost damage	☐	☐	☐	☐	☐	☐
Drought and forest fire	☐	☐	☐	☐	☐	☐
Damage due to poorer ground conditions	☐	☐	☐	☐	☐	☐
Pests such as bark beetles and root rot	☐	☐	☐	☐	☐	☐
Loss of biodiversity	☐	☐	☐	☐	☐	☐

5. How do you think these risks will change in next 50 years? Please respond on a scale from 1 = “Will become a lot less serious” to 5 = “Will become a lot more serious”

	Will become a lot less serious				**Will become a lot more serious**	**Don’t know**
Risks	1	2	3	4	5	
Storms	☐	☐	☐	☐	☐	☐
Flooding	☐	☐	☐	☐	☐	☐
Snow breakage	☐	☐	☐	☐	☐	☐
Browsing by herbivores	☐	☐	☐	☐	☐	☐
Frost damage	☐	☐	☐	☐	☐	☐
Drought and forest fire	☐	☐	☐	☐	☐	☐
Damage due to poorer ground conditions	☐	☐	☐	☐	☐	☐
Pests such as bark beetles and root rot	☐	☐	☐	☐	☐	☐
Loss of biodiversity	☐	☐	☐	☐	☐	☐

6. Which of these measures have to you taken in the last ten years and which five measures to you think are most effective to address climate change?

Forest management measures	**Measures taken in the last ten years**	**Most effective to address climate change**
Taking local conditions into greater consideration during planting or final felling	☐	☐
Shorter of rotation period between planting and final felling.	☐	☐
Increasing mix and diversity of tree species	☐	☐
Harder pre-commercial thinning and cutting	☐	☐
Forest management approaches that avoid clear-cutting (e.g. continuous-cover forest management)	☐	☐
Measures against insects and fungi	☐	☐
Improvements to drainage ditches	☐	☐
Salvage cutting and reforestation after storms	☐	☐
Investment into new equipment and roads	☐	☐
Insurance	☐	☐

7. How important was your own knowledge and experience with climate change when you decide to take one or more of these measures?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Not at all important — Very important — Don´t know

8. Are you planning to take risk-mitigating measures to address climate change in the coming five years?”

☐ Yes ☐ No

9. Can you please describe your experiences with the group discussions about climate change adaptation?

___

10. Have you learned some new during the discussions?

☐ Yes ☐ No ☐ Don't know

If yes, please describe what you have learned: ____

11. Have your views on climate risks and adaptation changed as a result of your participation in the group discussions?

☐ Yes ☐ No ☐ Don't know

If yes, please describe what you have learned: ____

12. Has the way in which you address climate risks and adaptation in your forest management changed as a result of your participation in the group discussions?

☐ Yes ☐ No ☐ Don't know

If yes, please describe what you have learned: ____

Appendix 9: Questions of the follow-up interview

General questions

1. Can you please describe your experiences with the group meetings?
2. Has your interest in climate change changed because of your participation in the meetings?
3. As a forest owner, have the meetings changed the way you look at the need to adapt to climate change and your ability to address future climate-related challenges?

Questions about scientific knowledge and communication

4. How much do you remember from the scientific presentations that were given during the second meeting?
5. How useful was this knowledge for you?
6. Have you observed changes in weather and climate conditions, and do you think they are related to climate change? Have your views changed since before the focus group meetings?
7. Have the meetings influence your view on the credibility of climate science? What can be done to improve the trust in climate science?
8. Has your ability to evaluate scientific knowledge about climate change changed as a result of the meetings?
9. What type of information and knowledge is needed by those involved in forest management.
10. Who do you think is most suited to communicate information and knowledge about climate change, and how should it be communicated?
11. How can information and knowledge about climate change be made for useful and accessible?

Knowledge exchange

12. Can you tell us about the different types of knowledge, academic and experience-based, that were discussed during the meetings?
13. What characterised the knowledge exchanged between forest owners and scientists during the meetings?
14. Are there other meeting places, platforms or informal settings that should be used for knowledge exchange between forest owners and scientists?

15. In your opinion what are key obstacles for knowledge exchange between forest owners and scientists?

Closing questions

16. Aside from the meetings, are there any other projects, events or factors that have influence the way in which you manage your forest?
17. Have you made new contacts as a result of the meetings?
18. Do you have any final comments about the meetings?

Final thank you

Appendix 10: Agenda of the workshop November 2014

Swedish forestry meets climate change

Workshop with forest owners from Skåne, Gävleborg, Jämtland and Västerbotten that participated in Mistra SWECIA focus group meetings

09:45 am Coffee, tea and sandwiches

10: 00 am Welcome

- Presentation of the Mistra-SWECIA research project and introduction to the workshop
- Presentation of all participants

10:45 am Presentation and discussion of Mistra-SWECIA's preliminary findings from the focus group meetings

- Preliminary findings and differences between the seven different groups
- Short update of scientific knowledge about climate change and its impacts on Swedish forestry

12:00 pm Lunch

01:00 pm Presentation and discussion of preliminary results from the national survey of Swedish forest owners and forestry advisors

- How are forest owners and forestry advisors viewing and acting on climate change

01:30 From Theory to praxis: Discussion about the way forward to address climate change in forest management in Sweden

03:00 pm Feedback and summary of discussion

03:20 pm Next steps and how will results from focus group meetings be used in future research

03:50 pm Final words

04:00 pm Final thank you

Appendix 11: Second ex-post questionnaire with participants in the focus group meetings (T-2)

Translated from the original Swedish. This questionnaire was distributed to forest owners at the end of the third and last group meeting in spring 2014.

1. Do you still own forest property?

   ☐ Yes ☐ No

2. Have you either sold or bought forest property in the past 4 years?

   ☐ Yes, I have sold forest
   ☐ Yes, I have bought forest
   ☐ No, I have neither sold nor bought forest

3. How much forest do you own today?

   ___

4. Please respond to the following statements on a scale from 1 = "Strongly disagree" to 5 = "Strongly agree"

Statements	**Strongly disagree** 1	2	3	4	**Strongly agree** 5	**Don't know**
I am very concerned about the global risk of climate change.	☐	☐	☐	☐	☐	☐
I am very concerned about the risk of climate change to my own forest.	☐	☐	☐	☐	☐	☐
I consider the global risk of climate change to be very serious.	☐	☐	☐	☐	☐	☐
I consider the risk of climate change to my own forest to be very serious.	☐	☐	☐	☐	☐	☐
I believe that my own forest is resilient enough to cope with climate change.	☐	☐	☐	☐	☐	☐
I believe that I have enough knowledge to adapt my forest to climate change.	☐	☐	☐	☐	☐	☐
I consider climate science to be trustworthy.	☐	☐	☐	☐	☐	☐

I need to take climate change into greater consideration. ☐ ☐ ☐ ☐ ☐ ☐

5. How will climate change impact your forest. Please respond on a scale from 1 = “Very negative” to 5 = “Very positive”

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐
Very negative				Very positive	Don´t know

6. Have you observed any changes in the weather or climate over the last 4 years?

☐ Yes ☐ No

If yes, please describe: ____

7. Has your forest been affected by extreme weather events in the past 4 years?

☐ Yes ☐ No

8. Do you believe that at least of these extreme events that your forest suffered from was caused by climate change? Please respond on a scale from 1 = “Strongly disagree” to 5 = “Strongly agree”

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐
Strongly disagree				Strongly agree	Don´t know

9. What is your opinion about the seriousness of following risks for your forest today? Please respond on a scale from 1 = “Not at all serious” to 5 = “Very serious”

	Not at all serious				**Very serious**	**Don’t know**
Risks	1	2	3	4	5	
Storms	☐	☐	☐	☐	☐	☐
Flooding	☐	☐	☐	☐	☐	☐
Snow breakage	☐	☐	☐	☐	☐	☐
Browsing by herbivores	☐	☐	☐	☐	☐	☐
Frost damage	☐	☐	☐	☐	☐	☐
Drought and forest fire	☐	☐	☐	☐	☐	☐
Damage due to poorer ground conditions	☐	☐	☐	☐	☐	☐
Pests such as bark beetles and root rot	☐	☐	☐	☐	☐	☐
Loss of biodiversity	☐	☐	☐	☐	☐	☐

10. How do you think these risks will change in next 50 years? Please respond on a scale from 1 = “Will become a lot less serious” to 5 = “Will become a lot more serious”

	Will become a lot less serious				**Will become a lot more serious**	**Don’t know**
Risks	1	2	3	4	5	
Storms	☐	☐	☐	☐	☐	☐
Flooding	☐	☐	☐	☐	☐	☐
Snow breakage	☐	☐	☐	☐	☐	☐
Browsing by herbivores	☐	☐	☐	☐	☐	☐
Frost damage	☐	☐	☐	☐	☐	☐
Drought and forest fire	☐	☐	☐	☐	☐	☐
Damage due to poorer ground conditions	☐	☐	☐	☐	☐	☐
Pests such as bark beetles and root rot	☐	☐	☐	☐	☐	☐
Loss of biodiversity	☐	☐	☐	☐	☐	☐

11. Which of these measures have to you taken in the past 4 years and which five measures to you think are most effective to address climate change?

Forest management measures	**Measures taken in the last ten years**	**Most effective to address climate change**
Taking local conditions into greater consideration during planting or final felling	☐	☐
Shorter rotation period between planting and final felling.	☐	☐
Increasing mix and diversity of tree species	☐	☐
Harder pre-commercial thinning and cutting	☐	☐
Forest management approaches that avoid clear-cutting (e.g. continuous-cover forest management)	☐	☐
Taking measures against insects and fungi	☐	☐
Improvements to drainage ditches	☐	☐
Salvage cutting and reforestation after storms	☐	☐
Investment into new equipment and roads	☐	☐
Having forest insurance	☐	☐
Other	☐	☐

If you chose other, please describe: ____

12. How important where the following factors when you decide to take one or more of these measures? Please respond on a scale from 1 = “Not at all important” to 5 = “Very important”

	Not at all important				**Very important**	**Don’t know**
Factors	1	2	3	4	5	
Advice from a forest consultant	☐	☐	☐	☐	☐	☐
Participant in Mistra-SWECIA group meetings	☐	☐	☐	☐	☐	☐
Personal knowledge and experiences	☐	☐	☐	☐	☐	☐
Other forest owners	☐	☐	☐	☐	☐	☐
Forest management plan	☐	☐	☐	☐	☐	☐
Forest magazines and journals	☐	☐	☐	☐	☐	☐
Other courses or workshops about climate change	☐	☐	☐	☐	☐	☐
Other	☐	☐	☐	☐	☐	☐

If you chose other, please describe: ____

13. What are your lasting impressions from the group meetings?

    ____

14. Have your views on climate risks and adaptation changed as a result of your participation in the group discussions?

    ☐ Yes ☐ No ☐ Don't know

    If yes, please describe what you have learned: ____

15. Has the way in which you address climate risks and adaptation in your forest management changed as a result of your participation in the group discussions? Please respond on a scale from 1 = "Not at all" to 5 = "To a very large extend"

    ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

    Strongly disagree — Strongly agree — Don´t know

    Please comment on your response: ____

16. Are you planning to take risk-mitigating measures to address climate change in the coming five years?"

    ☐ Yes ☐ No

    Please comment on your response: ____

Appendix 12: Changes in forest owners' preferences for forest management options to adapt to climate change

Appendix 12: Changes in forest owners' preferences for forest management options to adapt to climate change[1]

	Number and percentage of valid responses			McNamer's χ2 test	
Forest management option	**T-0**	**T-1**	**T-2**	**T-0/T-1**	**T-0/T2**
Taking local conditions into greater consideration during planting and final felling	29 (91)	29 (91)	28 (88)	χ2 = 0.00	χ2 = 0.14
Shortening rotation period between planting and final felling	17 (53)	17 (53)	17 (53)	χ2 = 0.00	χ2 = 0.00
Increasing tree-species mixture and diversity	20 (56)	20 (61)	21 (64)	χ2 = 0.33	χ2 = 0.69
Harder pre-commercial thinning and cutting	19 (58)	22 (67)	22 (67)	χ2 = 0.69	χ2 = .82
Forest management approaches that avoid clear cutting (e.g. continuous cover forest management)	5 (16)	3 (9)	2 (6)	χ2 = 1.00	χ2 = 1.8
Taking measures against insects and fungi	3 (9)	7 (21)	8 (24)	χ2 = 2.00	χ2 = 2.78
Improvements to drainage ditches	22 (67)	25 (76)	20 (61)	χ2 = 0.82	χ2 = 0.33
Salvage cutting and reforestation after storms	10 (33)	7 (23)	11 (37)	χ2 = 1.00	χ2 = 0.08
Investment into new equipment and roads	14 (47)	19 (60)	8 (30)	χ2 = 1.60	χ2 = 2.78
Having forest insurance	9 (30)	6 (20)	5 (17)	χ2 = 1.23	χ2 = 2.67

[1] Only includes responses from forest owners that respond to all three questionnaires. N: 35